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Maize Research Impact in Africa: The Obscured Revolution

Complete Report

Elon Gilbert, Lucie Phillips, William Roberts,
Marie-Therese Sarch, Melinda Smale, and Ann Stroud
with
Edgar Hunting

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Productive Sector Growth and Environment Division
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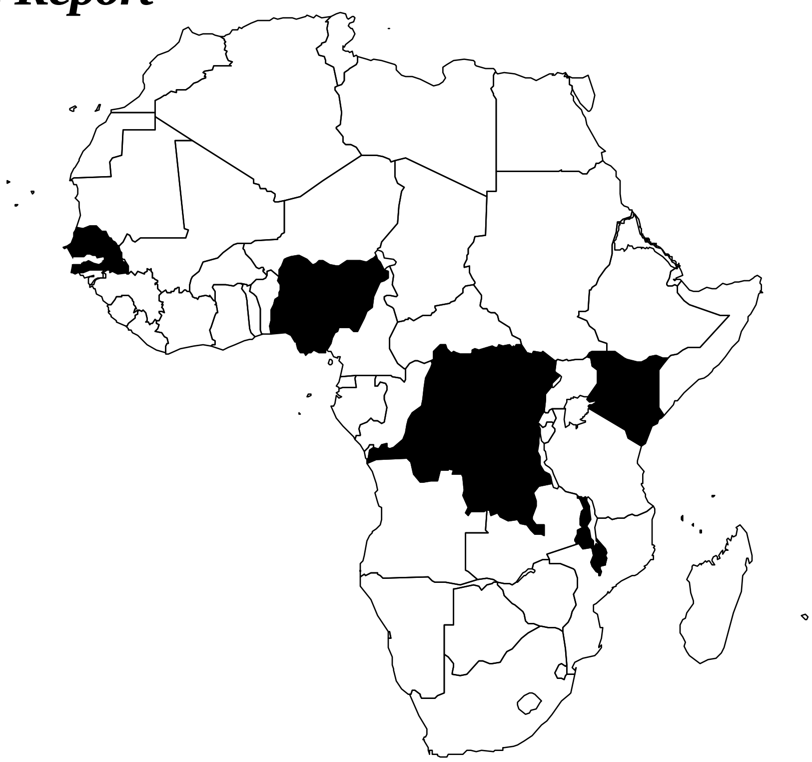

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Contents

Foreword

The study *Maize Research Impact In Africa: The Obscured Revolution* was started in 1990 as part of an initiative by the U.S. Agency for International Development, Africa Bureau (USAID/AFR) to improve its accountability for development change resulting from investments in agricultural technology development and transfer (TDT). The findings presented in this study broaden our knowledge of the impact past investments have made and provide useful lessons regarding analytical tools available for progress monitoring and impact assessment of agricultural TDT activities.

The concern for development impact from investments in agriculture in Africa has increased in the four years since this study began. In the future, the concern for impact will be a fundamental issue guiding the choice of development investments. Although this early effort in examining the impact of research in Africa began at a time when there was little factual evidence, it will play an important role in guiding future progress-monitoring and impact-assessment activities.

This report will be especially useful to those policymakers and groups that have made significant investments in maize research and development in Africa over the past 20 years. The study chronicles investment trends in maize in Africa, and examines what would have happened to food supplies if this development investment had not been made. It also provides detailed information at the national level for five countries: Kenya, Malawi, Nigeria, Senegal, and Zaire. In addition to the findings on impact, the study found that many impacts resulting from the use of new technology are hidden, especially in the area of labor shifts—made possible by increased productivity.

The individual country case studies have been synthesized in this main report. Full copies of the country case studies are available on request from the Africa Bureau's Office of Sustainable Development / Productive Sector Growth and Environment Division (AFR/SD/PSGE).*

Completion of this study has involved many individuals and groups. I especially acknowledge the important role of Elon Gilbert, the team leader, in this study, as well as the other team members. The U.S. Department of Agriculture, Office of International Cooperation and Development, played a key role in assembling the study team and supporting this study. I also acknowledge the important contribution and guidance provided by various USAID technical officers in the course of this study, including Lance Jepson, Thomas Hobgood, Michael Fuchs-Carsch, and Dwight Smith. Finally, I extend a special thanks to the many USAID Missions and National Agricultural Research System leaders in Africa that participated in and supported this study.

David M. Songer
TDT Unit Leader
USAID/AFR/SD/PSGE

* Formerly the Office of Analysis, Research, and Technical Support / Division of Food, Agriculture, and Resources Analysis (USAID/AFR/ARTS/FARA)

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The MARIA study received assistance from many people on three continents - too many to adequately acknowledge everyone. Special recognition goes to the following people who assisted at various junctions in providing guidance, reading and commenting on drafts, arrangements for visits, administrative matters, and report preparation.

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Executive Summary

The Maize Research Impact in Africa (MARIA) study examines the changes on African economies produced by innovations for maize since the 1960s. The study forms part of an effort by the Africa Bureau of the U.S. Agency for International Development (USAID) to assess returns to the investments in agricultural research made by African governments and donors over the past three decades. The choice of maize reflects the attention given to the commodity by research services (national and international), development projects, and policy reforms, as well as its importance in staple food economies of the region. Most significantly, maize was selected because measurable progress has been made across a broad spectrum of ecologies, farming systems, and political-economic conditions.

By conventional measures, maize is a success story. Production in sub-Saharan Africa (SSA) has grown on average by 2.6% annually over the past 25 years and outpaced all other coarse grains and AGDP by significant margins. Comparing actual production levels to "without research" scenarios where maize yields either stagnated or declined, SSA data suggest levels of impacts that are at least moderately impressive. The diversity of conditions, however, has affected the magnitude and character of these impacts. Five individual country case studies—Kenya, Malawi, Nigeria, Senegal, and Zaire—explore both the changes associated with the adoption of innovations by farmers in different regions of Africa, and the differences in impacts at the national, district, and farm family levels.

The evidence strongly supports the proposition that research contributed to increased returns to both labor and land and thus to the competitive position of maize in relation to other enterprises. Changes in production and productivity must be viewed in the context of resource allocation decisions by millions of farm families who vary widely in their resource endowments. Innovations in maize production and postharvest practices form part of a broad process of adjustment to adversity and response to opportunity that is fundamentally altering agricultural sectors in the SSA region. The response to innovation is related to the position of maize as a food and cash crop in farming systems. Where maize is already the dominant staple, as in Kenya and Malawi, low-resource farmers are apt to use innovations to save resources for allocation to other activities.

Research carried out at the national level has played a major role in improvements in maize production and productivity. Maize research program performance is a function of adequate resources and quality management, as well as the quality and continuity of research staff. Favorable conditions or "windows of creativity," however, have occurred only episodically and were sustained more by the force of personalities than by money, infrastructure, or institutional logic. MARIA suggests that the process of strengthening National Agricultural Research Systems should include special attention to improving the performances of individual researchers under adverse conditions. Towards this end, ways must be found to open more windows for the best of Africa's researchers to be creative in order to accelerate the flow of innovations required for development.

Glossary of Acronyms and Abbreviations

AFR	Bureau for Africa (USAID)
ARTS/FARA	Office of Analysis, Research, and Technical Support / Division of Food, Agriculture, and Resources Analysis (USAID/AFR, now SD/PSGE)
AGDP	Agricultural Gross Domestic Product
ADP	Agricultural Development Project
CFAF	Franc de la Communaute Francophone Africaine (West African currency unit, 1 French franc = 50 CFAF; $1 U.S. = approx. 300 CFAF)
CIMMYT	Centro Internacional de Mejoramiento de Maiz y Trigo (International Maize and Wheat Improvement Center)
CIRAD	Centre de Cooperation Internationale en Recherche Agronomique pour le Developpement
FAO	Food and Agricultural Organization
FSR	farming systems research
GDP	gross domestic product
HYV	high-yielding variety
IAR	Institute of Agricultural Research
IARC	International Agricultural Research Center
ICRISAT	International Crops Research Institute for the Semi-Arid Tropics
IITA	International Institute for Tropical Agriculture
ISRA	Institut Senegalais de Recherche Agricoles
KARI	Kenya Agricultural Research Institute
MARIA	Maize Research Impact in Africa Study
MSU	Michigan State University
MSV	Maize Streak Virus
MT	metric ton
NAP	New Agricultural Policy
NARS	National Agricultural Research System
NCPB	National Cereals Produce Board (Nigeria)
NGO	nongovernmental organization
OPV	open-pollinated variety

PNM	Programme National Mais (Zaire)
PNS	Project North Shaba (Zaire)
RDA	Regional Development Association
R&D	research and development
ROR	rate of return (also ROR study carried out by MSU)
RRA	Rapid Rural Assessment
SD/PSGE	Office of Sustainable Development / Productive Sector Growth and Environment Division (USAID/AFR, formerly ARTS/FARA)
SPAAR	Special Program for African Agricultural Research (World Bank)
SSA	sub-Saharan Africa (excluding the Republic of S. Africa)
USAID	U.S. Agency for International Development
USDA	U.S. Department of Agriculture

1. Introduction

The Maize Research Impact in Africa (MARIA) study examines the changes produced by innovations for maize on African economies since the 1960s. The study forms part of an effort by the Africa Bureau of USAID to assess returns to the investments in agricultural research made by African governments and donors over the past three decades.[1] The choice of maize reflects the attention given to this commodity by research services (national and external), development projects, and policy reforms, as well as its importance in staple food economies of the region. Most significantly, maize was selected because measurable progress has been made across a broad spectrum of ecologies, farming systems, and political-economic conditions.

The purpose of the study is to assess the maize research impact in sub-Saharan Africa (SSA) on food availability, nutrition, trade, economic growth, and transformation. The heterogenous nature of the region, the character of the economies, and the directions of change make many of the most important impacts difficult to measure. Available socioeconomic data often produce contradictions that go beyond deficiencies in the basic numbers.

The study explores the nature and extent of impacts from technological change in maize production, and the role of research by national and external research agencies in that process. At the same time, the analysis raises questions about elements of past support. The lessons learned are relevant to future research and development efforts for maize and other subjects, although the study is not intended to provide detailed proposals for support in these areas.

STUDY SCOPE AND APPROACH

The MARIA study was carried out by a team of researchers over an 18-month period commencing in January 1991.[2] Kenya, Malawi, Nigeria, Senegal, and Zaire were selected as the principal country case studies (see title page). Information was collected for three additional coun-

1. This study is being done under contract to the Office of International Cooperation and Development (OICD) of USDA. Annex A includes the original Scope of Work for the study together with the modifications extending the study into a second phase. Related research includes: 1) A study of rates of return to agricultural research, with case studies in seven countries (Mali, Kenya, Malawi, Cameroon, Zambia, Uganda, and Niger), which is being undertaken by the Department of Agricultural Economics at Michigan State University (MSU); and 2) a study of intermediate research impact indicators by Management Systems International (MSI). The research team expresses its appreciation to the Africa Bureau of USAID and its country missions for the cooperation throughout the conduct of the study. The authors have sole responsibility for the views expressed in the study reports which are not necessarily shared by USDA; Productive Sector Growth and Environment Division, Office of Sustainable Development, Bureau for Africa, U. S. Agency for International Development; or the missions.

2. The research team includes Elon Gilbert (agricultural economist and team leader); Lucie Colvin Phillips (socioeconomist); William Roberts (anthropologist), Marie-Therese Sarch (agricultural economist), Melinda Smale (agricultural economist), and Ann Stroud (agronomist). Collaborators for the country case studies include Victor Doulou (Congo), Koko Nzeza (Zaire), Daniel Karanja (Kenya), and Musa Mbenga (The Gambia). The analysis of the “with and without” scenarios was performed by Edgar Hunting. Joan Robertson and Christina Fairchild were responsible for editing and report production, respectively.

tries—The Gambia, Congo, and Ethiopia— although formal reports on these countries are not included in the MARIA study.[3]

The five case-study countries collectively contain 39% of the population of the region and 28% of total maize production. These countries were not selected as being "representative" of the SSA region although they do include a broad spectrum of geography, ecologies, policy contexts, research and development efforts, and farming systems. Rather, they are countries in which research and development efforts for maize have produced measurable change.

MARIA draws extensively on existing studies and secondary sources, but also utilizes insights from "key informants" including researchers who participated in maize improvement efforts in the region and maize farmers. The study is a collaborative effort involving research team members, most of whom are resident in Africa, and colleagues who were involved with the case studies for individual countries. For each case-study country, consultations were held with representatives of the USAID missions and the national agricultural research system (NARS); their specific interests and questions were addressed through the case studies as time and resources permitted.[4]

A SUCCESS STORY

By conventional measures, maize is a success story. Production in SSA has grown on average by 2.6% annually over the past 25 years. The increase is traceable to both improvements in yield and expansion in area. While this is not equivalent to population growth, the increase of maize production has outpaced all other coarse grains and AGDP by significant margins.

Two Scenarios

The most obvious impact of maize research is the change in the amount of grain that is produced. MARIA measures the part of production change that can be traced to research through comparing actual production with different scenarios expressing what might have existed without maize research (Figure 1.1). The key variables used in the "without research" scenarios are yield and the area devoted to maize cultivation. The scenarios take account of shifts in area to maize from other coarse grains, particularly sorghum and millet.

Scenario I (Static yield) assumes that without maize research, the yield of maize would have remained at its 1966–70 five-year-average level. In this scenario the area devoted to maize cultivation is allowed to expand as a constant proportion of the area actually put to coarse grains, including maize, sorghum, and millet. For example, if maize accounted for half the total area planted to coarse grains during 1966–70, then it is assumed that the area planted to maize would continue to account for 50% of coarse grain area through to 1990. If technologies were absent, resource productivity and the attractiveness of maize production compared to other coarse grains would have remained unchanged.

Scenario II (Declining yield) takes account of the effects of pests, diseases, and declining soil fertility. Research has been responsible for incorporating pest and disease tolerance into improved germplasm as well as providing a range of approaches for maintaining soil fertility. This scenario assumes that average yields would have fallen by 1% each year in the absence of these innovations. Sorghum and millet account for all expansion in coarse grain area. In essence, Scenario II postulates that, as a consequence of declining yields, maize would progressively lose its competitive position compared to other coarse grains.

These scenarios represent two points in a range. While Scenario II is arguably on the

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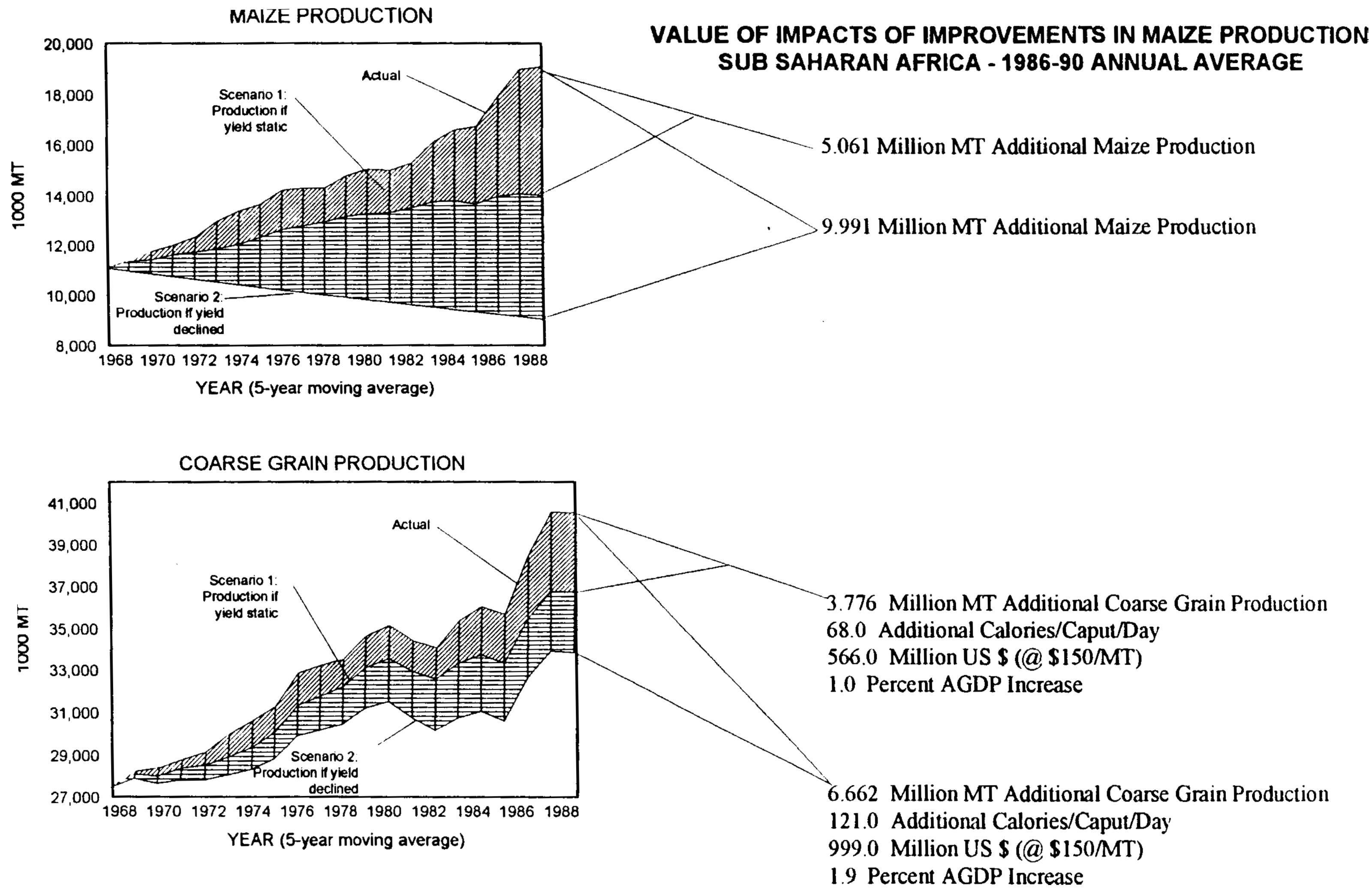
3. A report is being prepared on the Impact of Maize Research in The Gambia with support from outside the project.

4. The methodology and program for the study is included in Annex B (Methodology).

Figure 1.1. Sub-Saharan Africa Maize and Total Coarse Grain Production, with and without Technological Change



Source: See Annex D.

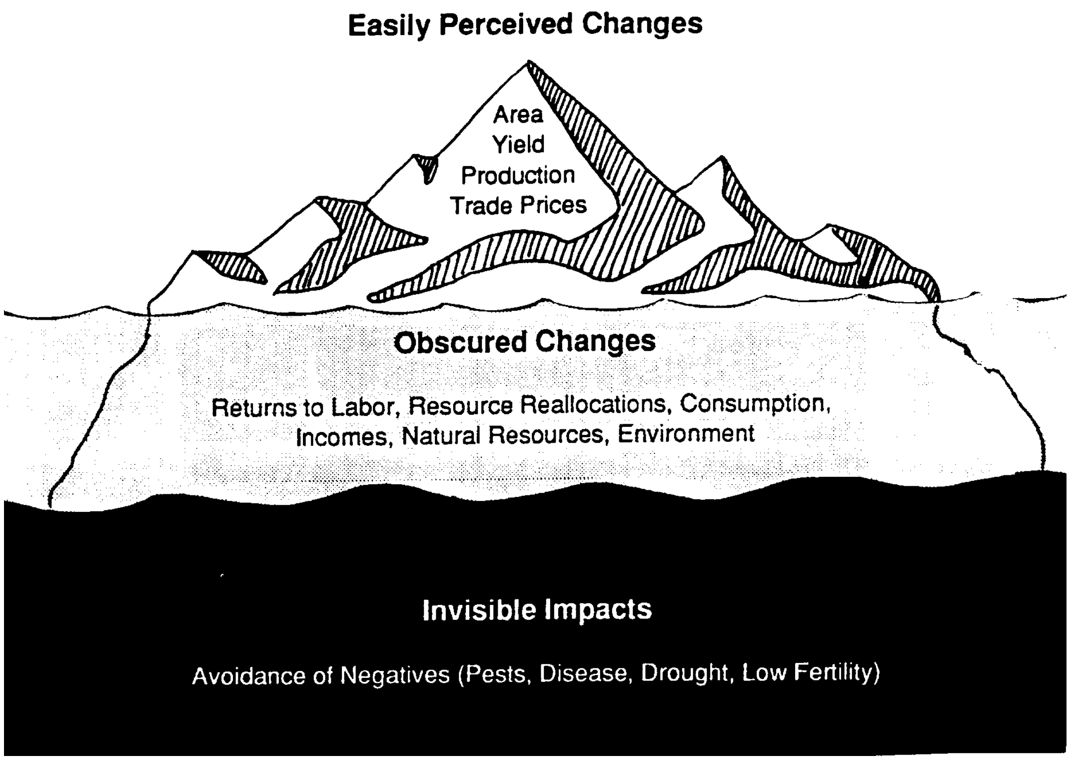
pessimistic side, there is no basis to assume that declining yield is a less plausible assumption than simply no change in the absence of research-led innovation. Improvements in production brought about by farmer innovation also lie within this range.

With these scenarios it is possible to estimate the impact of maize research as the increment in maize production that has occurred over and above the level that would have been achieved without improved technology. For Scenario I (Static Yield) the increment is illustrated by the bold hatched portions of Figure 1.1. Scenario II (Declining Yield) produces a larger gap, as indicated by the entire hatched portions of Figure 1.1. The resulting additional production or gaps can be expressed in terms of calories per capita per day, reductions in imports, and increases in AGDP. From 1986 to 1990, these translate into average annual improvements in maize production of between 5.1 and 10 million metric tons (MT), and additional coarse grain production of between 3.8 and 6.7 million MT. These production increases equate to annual reductions of between US$566 and $999 million in imports, and increases in AGDP of between 1.0 and 1.9%.

Using these scenarios, SSA regional data suggest levels of impacts that are at least moderately impressive. However, the diversity of the subregions of West, Central, East, and Southern Africa has affected the magnitude and character of these impacts. In both relative and absolute terms, data show that maize technologies have had the largest impact on production in East Africa where maize is the primary staple food. In contrast, impacts on maize production in West and Central Africa are not immediately obvious, and are associated with changes in climate, input supply, markets, and farming practices.

The purpose of the individual country case studies is to explore both the changes associated with the adoption of innovations by farmers in different regions of Africa, and the differences in impacts at the national, district, and farm family levels.

Figure 1.2. The Impact Iceberg



The Impact Iceberg

The impacts estimated through "with and without innovations" comparisons are only one aspect of a complex process of transformation. The true character and dimensions of this change are eclipsed by cross currents of policy, environmental changes, war, peace, and structural adjustment. These have ebbed and flowed across the region during the past three decades and have obscured evidence of transformation in the same way as water conceals the larger part of an iceberg (Figure 1.2).

The changes in production and productivity that have occurred must be viewed in the contexts of resource allocation decisions by millions of farm families. These farmers vary widely in their resource endowments and thus in the type and scale of benefits derived from adoption and utilization of new maize technologies. Innovations in maize production and postharvest practices form part of a broad process of adjustment to adversity and response to opportunity that is fundamentally altering agricultural sectors in the SSA region. These innovations have increased productivity levels relative to what they otherwise would have been. Improvements in yields usually, but not universally, indicate increases in productivity. For the majority of SSA farm families, however, the productivity of their labor and the stability of their food production are primary concerns.

Thus, a major challenge for the study was to identify and trace impacts at the farm level from research-related changes in input/output relationships and resource reallocations. The upsurge in interest in such impacts has highlighted serious limitations in using existing national data sets to assess aggregate responses to these microlevel changes.

Factors

Research is only one of several factors contributing to changes in production and productivity. Others include environmental change, promotional efforts, price policies, and the nature of the farming systems themselves. While it is difficult to precisely delineate the contributions of any one factor, special attention is given to the role of research because, without research-generated innovations, the impacts of any other factor would be considerably diminished. MARIA is *not*, however, a comprehensive review of maize research in the region or even of selected countries. Nor does the study attempt to assess the quality of maize-related research that was carried out by specific institutions and programs, although considerable information on both these subjects is included in the country case studies. Rather, the study illustrates that at specific points and locations (e.g., project areas or districts in individual countries), innovations—the products of research—were successfully identified, adapted, and extended to farmers and resulted in positive changes in productivity.

STRUCTURE OF THE REPORT

This report consists of three major components:

- Chapters 1 and 2 provide a general conceptual and contextual framework for the MARIA study. The brief overview of approaches utilized for the study in Chapter 1 is supplemented by an elaboration of the methodology in Annex B. The central hypotheses for the study grow out of the contextual review presented in Chapter 2.
- The central component of the report consists of Chapters 3 and 4, which summarize the five principal case studies and the impacts of innovations at the subregional level, respectively.
- The final two chapters present conclusions and lessons learned, drawing upon all case studies.

2. Context

The description of the SSA regional context in this chapter draws upon a number of current studies of developments in the region, including those carried out under the auspices of the World Bank.[1] These and other reports offer interpretations of trends in SSA that range from gloom to guarded expressions that things are getting better.[2] The changes in maize production and productivity that have taken place in SSA are at least moderately impressive. Against the backdrop of what has been happening in the economies and agricultural sectors of most countries in the region, the performance of maize is even remarkable. The experience with maize demonstrates what can happen when sustained introduction of technological innovations coincides with the reduction or elimination of civil unrest, perverse policies, and mismanagement.

Development trends in SSA that emerge from the regional context of this study are an important source of the hypotheses examined in the study and provide a background for better understanding its conclusions and lessons learned on the contributions of maize research. The chapter begins with a summary of development trends in SSA during each of the past three decades with a focus on the agricultural sector. The discussion is extended to review trends in the capacity and performance of agricultural research institutions in the region. This is followed by an overview of the position of maize in the food economies of SSA and the rationale for its selection as the commodity focus for the impact study. The chapter concludes with the hypotheses selected for the MARIA study.

1. Notable examples include *Managing Agricultural Development in Africa (MADIA); From Crisis to Sustainable Growth in Sub-Saharan Africa* (World Bank, 1989b); and most recently *The Population, Agriculture and Environment Nexus in Sub-Saharan Africa* by Cleaver and Schreiber (1992).

2. A good illustration of the latter is J. Wolgin, “Fresh Start in Africa” (1990).

DEVELOPMENT TRENDS

Each of the three decades since Africa’s independence period has witnessed major shifts in strategies for economic and agricultural development in the region. These shifts have had important consequences for the character of agricultural research and the extent of its impact upon the agricultural sector.

The 1960s

In the 1960s, the immediate postindependence period for most African countries, the target was nothing less than transforming the economies into modern, industrialized societies with governments playing a leading role. It was assumed that the agricultural sector, particularly the traditional export commodities, would shoulder a major portion of the financial cost in addition to supplying the labor requirements.[3]

Governments made major investments in infrastructure, including transport, communications, and medical facilities, and dramatically accelerated the pace of human resource development through the expansion of educational institutions at all levels. Spearheaded by Ghana, many African countries also launched a series

3. There are several expositions of this view, the most influential of which is probably that of Sir Arthur Lewis (1954).

of public enterprises to promote rapid growth in virtually every major sector. It was hoped that dependence on traditional trade (basic commodities for manufactured goods) with developed countries would be replaced by an African-managed, pan-African economy that was progressively able to meet its own needs.

The transformation strategy had important consequences for the agricultural sector:

- *Migration* to urban centers expanded dramatically in response to the raised expectations that accompanied independence. The movements included a growing percentage of long-term migrants including women and entire families. Migration and the expansion of educational opportunities for the young in effect withdrew large quantities of labor from traditional agricultural enterprises.
- *Declining world prices* for many traditional export commodities, together with continued taxation imposed by government statutory monopolies, led to a sharp deterioration in incomes for most agricultural producers.
- *"Modern" commercial agriculture*, consisting of an assortment of state enterprises, collectives, and cooperatives, was the focus of government efforts to develop the sector in many countries. Many large-scale, non-African agricultural enterprises from the colonial period were nationalized, dismembered, or forced into joint ventures with public sector institutions.

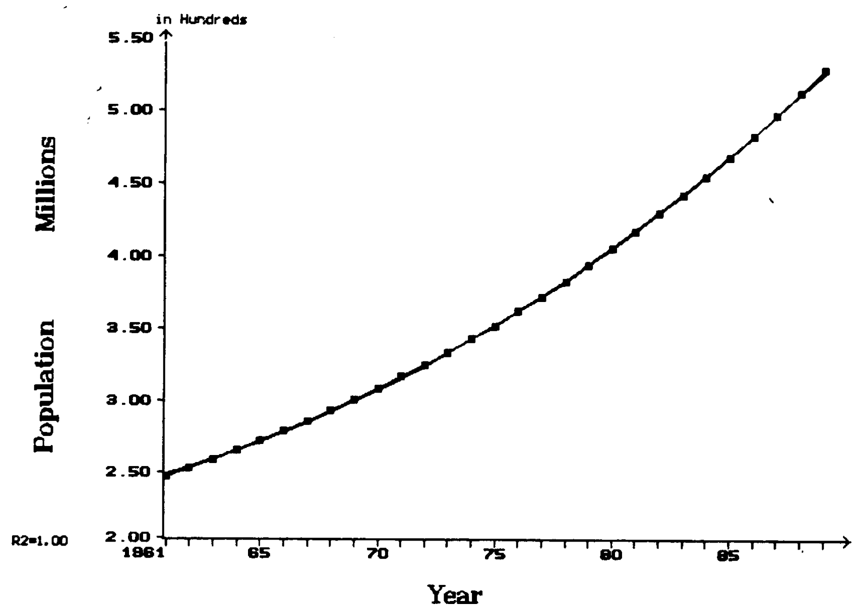
These conditions reinforced the view of many farm families that their futures, or at least the futures of their children, did not lie in traditional, smallholder agriculture. Although agricultural production continued to make progress during the early and middle 1960s, this was largely due to the momentum from the colonial period. Most of the state enterprises failed to develop modern commercial agricultural sectors; AGDP began to droop in the late 1960s and plunged in the early 1970s as disinvestment in the sector combined with perverse policies and drought. The region that had been basically self-sufficient in staple foods moved sharply into a deficit position. A significant portion of development efforts during the 1960s was funded by the governments themselves from reserves, loans, and suppliers' credit.

The failure of rapid industrialization and transformation under government leadership resulted in a growing accumulation of external debt and large, unevenly functioning bureaucracies. The authority, capabilities, and integrity of the elite who had assumed power at independence were increasingly challenged in the form of military coups and separatist movements, some of which gave rise to prolonged and debilitating conflicts.

There were, however, a few notable exceptions to the above characterizations. Kenya, Malawi, and Ivory Coast preserved and strengthened major portions of the agricultural infrastructure inherited from the colonial period (research, extension, and marketing institutions), although with a shift in emphasis toward African producers. More broadly based progress in the agricultural sectors in turn fueled the expansion of other sectors in these countries.

Population growth accelerated from 2.7% (1965–80) to 3.1% (1991) (see Figure 2.1) as the result of improvements in preventative care. Mass vaccination campaigns and health education via rural radio contributed to a sharp reduction in infant mortality and, wherever peaceful conditions prevailed, mortality rates continued to decline. For individual families, however, success in keeping their children alive and diversifying and securing their future did not translate into a reduced demand for children. Thus, for national health and educational institutions, the result was a growing financial drain on governments and deteriorating quality of services. Unemployment in the urban areas escalated; far more young people entered the labor force each year than could be absorbed by new lands settlement in rural areas or job creation in the cities.

Figure 2.1. Sub-Saharan Africa Population



Source: See Annex D.

The 1970s

The general failure of rapid industrialization strategy and the widespread drought of the early 1970s led governments and donors to shift their attention toward food security and alleviating poverty and socioeconomic inequities. Greater attention was given to improving the productivity of small, low-resource farmers through research and development activities, including, for the first time in several countries, a focus on food crops. Development efforts were extended to marginal areas where a significant portion of the "poorest of the poor" were found. Special attention was given to women to ensure that they received a larger share of the benefits from donor assistance.

The flow of capital into Africa increased sharply in the 1970s. Petroleum-exporting countries joined to raise prices, and the resulting surge in revenues stimulated a search for productive investments, which depressed interest rates worldwide. Donor assistance expanded, partially in response to the great Sahelian drought, and was accompanied by a wave of bilateral government investment throughout SSA. Gross investment grew from 15% of GDP in the 1961–73 period, to 20.6% in 1973–80 (World Bank 1989b). Within a few years, however, the low returns to this investment were evident, and economic decline continued.

The shift in strategic focus toward reaching small, low-resource farmers, particularly in marginal areas, strengthened the position of public sector institutions since it was argued that the private sector could not or would not serve this group of clients. However, there were very few examples of perceptible improvement in the performance of public sector institutions. In most countries, governments cemented their patronage networks by expanding already plethoric bureaucracies. Operating budgets declined, however, so that even highly motivated civil servants could not function adequately.

Donors were determined to see their aid reach poor farmers, and governments wanted to spread development efforts to hitherto neglected parts of their territories. With food security their aim, new agricultural technologies were introduced to marginal zones with minimal adaptation to local conditions. Food aid and the introduction of irrigation schemes encouraged some farmers in drought-prone areas to remain there. However, the schemes suffered from poor management, low cropping intensities, shortages of fuel and spare parts, and poor access to markets.

The expansion of infrastructure into these areas (mainly year-round roads and telecommunications) created the basis for broad national economies, but markets remained fragmented and inefficient. Export crop marketing boards began raising their producer prices and, by the end of the decade, they sometimes announced prices for export crops that turned out to exceed world market levels, reducing or eliminating export earnings and putting governments to severe financial strain. Only in countries with significant European settler populations (Kenya, Angola, Mozambique, and Zimbabwe) did the marketing boards and nationwide credit schemes function fairly consistently for several decades. They were not run by settlers, but the presence of vocal commercial farming communities, both African and white, seemed to serve as a corrective, keeping them within viable limits.

In many African countries, the seventies also saw the rise of integrated rural development projects (IRDPs) which, it was argued, would be more effective in reaching the rural poor and serving disadvantaged areas. The projects spawned a generation of regional development agencies (RDAs) that were meant to simultaneously decentralize, integrate, and streamline the direction of development activities within project areas that roughly coincided with provincial or district/department boundaries. But RDA activities often included services for agriculture, health, and infrastructural development that cut across the purviews of several existing ministries and departments causing jurisdictional disputes, confusion, and competition for staff and resources.

Unfortunately, the RDAs were as ineffective as their national-level predecessors in serving the needs of local communities; most of them faded away during the late 1970s and early 1980s with the decline in donor support for the IRDP approach. Agricultural research produced the most cost-effective food security in the end, introducing early-maturing, drought-evading, and pest-tolerant cereal varieties.

The 1970s marked a major surge in efforts to strengthen national agricultural research systems (NARS) and expand the services of the International Agricultural Research Centers (IARCs) in the region. This was accompanied by considerable indiscriminate bashing of research institutions and networks inherited from the colonial period in the name of shifting the focus to food crops and generally making a clean break with the past. Although considerable progress was made on both fronts, by the end of the decade there were still very few examples of well-managed, functioning NARS in the region. The NARS were not immune to the diseases of corruption, mismanagement, tolerance of low performance, and the general lack of accountability that had progressively permeated the public sectors of nearly every African country.

With a few notable exceptions (maize being one), there was limited progress in either instilling new life into the agricultural sector or helping the principal target group: the small, low-resource farmers in marginal areas. By the end of the decade, Africa was deeper in debt and more dependent on the developed world for nearly everything, including food, than it had been at any time in its history.

There was growing confusion and frustration with the limited progress in transferring "clearly superior" innovations to small farmers in many parts of the region. Belatedly, researchers and extension staff began to realize that farmers were less than enthusiastic about most of the improved technologies. These concerns led to the rise of farming systems research (FSR) in the late 1970s (Gilbert, Norman, and Winch

1980).[4] The earlier top-down orientation began to be replaced by better understandings of farmer constraints and farmer participation in the testing of innovations. These insights provided direction to research and development efforts with the result that small, low-resource farmers in marginal areas finally began to be properly served.

Despite continuing efforts to simultaneously alleviate poverty and get agriculture moving, the performance of the sector moved downward. Drought, war, mismanagement, and counterproductive policies conspired to obstruct serious efforts at improving conditions in many countries. Nearly half the countries in southern Africa (Zimbabwe, Mozambique, Angola, Namibia) spent much of the decade at war, as did Sudan, Ethiopia, and Uganda in East Africa. Many of these conflicts persisted through the 1980s with a concurrent rise in numbers of refugees and dependence on food aid.

Quite aside from the adversity of sociopolitical and macroeconomic contexts, research efforts were technically poorly focussed. The traditional export crops continued to be neglected. Even identifying improvements for low-resource farmers in marginal areas, which might have made a significant difference, proved far more elusive than anyone had anticipated. Nevertheless, large amounts were expended on research and development projects with the result that there was little to show for it after the projects closed down.

Increasing population pressures on available land did not result in the widespread adoption of yield-enhancing technologies by farmers. Studies carried out during the period confirmed that labor, rather than land, continued to be the most binding constraint to increased production (Binswanger 1986). The timing of farm operations (e.g., planting, weeding) became critically important and aggravated labor constraints. However, the labor constraint, together with a substantial reduction in average annual rainfall across the Sudanic and Sahelian zones, did have one positive effect: the reduction in vegetative cover that accompanied the lower rainfall reduced the tsetse challenge and improved the feasibility of equine traction.

4. More than 10 years earlier, a variant of FSR/E had been initiated in Senegal through the Unite Experimentale of the Institut de Recherche Agricole du Senegal (ISRA) (Benoit-Cattin 1986; Faye and Bingen 1989).

The 1980s

By the early 1980s Africa found itself outdistanced and losing ground to the developing countries in other regions, especially South Asia and the Pacific Rim. There was increasing concern about the statistics—declining per capita income stemming from a combination of rapid population growth and poor performance. Shortage of foreign exchange became a general phenomenon in countries with nonconvertible currencies, particularly those outside the franc zone. Government efforts to curb demand for imports through finely tuned controls and licensing had dramatically expanded the opportunities for abuse. The agricultural sector continued to perform unevenly; export earnings declined and there were few clear examples of the transformation and intensification that were expected to accompany population pressures and the availability of yield-enhancing innovations.

The investments of the 1960s and 1970s were not yielding returns adequate to produce growth. More disturbingly, the performances of public sector institutions were not responding to massive investments in training, equipment, and infrastructure; they continued to function at low or even declining levels. External debt grew at an alarming rate and, with it, a growing lack of donor enthusiasm for sub-Saharan investments.

A change in the orientation of donor approaches to dealing with the region was signaled by the Berg report (World Bank 1981), which focused directly on the set of policies and public sector institutions that had guided development efforts since independence. The report called for a major shift in emphasis toward reliance on market mechanisms and the private sector. Although there was still concern for equity, gender, and food security issues, there was a clear shift in direction toward resuscitating exports and the higher-potential agricultural areas.

Despite considerable doubts and resistance on the part of many national governments about the conclusions of the Berg report, structural adjustment and reform emerged as the cornerstone of development efforts in SSA. Donor agencies, led by the World Bank and IMF, increasingly required adjustments in policies governing the management of trade, foreign exchange, public sector expenditures, and money supply, as conditions for further external support. While these reforms cut to the heart of vested interests in many countries, they were increasingly championed by groups of reform-minded senior officials in ministries and planning agencies, and especially by representatives of the private sector.

The shifts in development strategy impacted on the agricultural sector in several ways:

- The reforms extended to adjustments in pricing and trade policies, generally improving the terms of trade in favor of agriculture. The policy of cheap food that primarily benefitted the urban areas was reversed, allowing prices to increase in many countries and reducing government subsidies. However, there was still a large and, in some instances, growing dependence on food imports and food aid.
- The producer prices of traditional export crops rose as taxes were reduced or eliminated, and efforts were made to improve export marketing through reforms of public sector marketing institutions and greater private sector participation.
- Deregulation of input marketing led to improved availability in some instances, but at significantly higher prices, particularly for fertilizers; higher prices and credit reforms reduced its utilization.

In the latter part of the decade, the focus of reforms spread to agricultural research and extension organizations. Structural adjustment improved the conditions for growth and transformation, but a flow of productivity-increasing innovations was necessary to sustain this process beyond the initial windfalls from the removal of perverse policies.

In 1985, USAID issued a strategy statement reaffirming its commitment to strengthen national research capacity in Africa (USAID 1985). Although efforts to increase capacity through training and technical assistance continued throughout the region, special attention was given to those countries and institutions that could generate technologies for use by their neighbors as well as themselves. This position reflected the view that a critical mass of researchers and a high level of institutional capacity were necessary to conduct research on specific commodities and produce results. Concentrating on the few countries with existing or potential capacities to perform this role was expected to enhance the chances of success and benefit the region as a whole. On the other hand, continued dissipation of resources and efforts across the entire range of unevenly functioning NARS was considered unlikely to produce the desired results.

The new strategy directions for research were unevenly applied, especially in the face of strong pressures from national research institutions and local USAID missions to continue general support to NARS in most countries in the region. Local support continued, but there were growing doubts that the existing core set of public sector institutions could do the job. Performance levels appeared to be sinking, and expanding private sector opportunities depleted many research and extension institutions of their most able staff.

A landmark paper by Eicher (1989) questioned whether the costly but spasmodic efforts to develop research institutions in SSA were making progress in any direction other than creating large establishments that national governments were unlikely to support in the medium term. Although the attention to FSR/E in the early 1980s helped to improve the understanding of farming systems and client needs, FSR/E teams often found themselves in adversarial roles vis-à-vis commodity improvement programs (Collinson 1982; Merrill-Sands et al. 1991). Further, the capacities of most NARS were declining, so a better understanding of client needs did not translate into an expanded flow of appropriate innovations. The conditions in which many NARS found themselves in the late 1980s and early 1990s was the antithesis of those that promote performance and creativity. Weak linkages between research and extension were often blamed for the limited progress in the production and adoption of innovations, but poorly functioning institutions on both sides were also a major factor.

An additional dimension was that FSR/E and other efforts were producing a much more complex research agenda. The specifications for improved technologies were becoming more exacting and location-specific in nature. As the decade closed, attention turned increasingly to sustainability, both of agricultural production and the environment. The increasing complexity of the research agenda in turn widened the gap between farmers' needs on the one hand, and the capacity and performance of the research services, both national and external, on the other.

The Present

The SSA region today is in the throes of a deepening economic crisis. The effects of a growing debt burden is compounded by drought and civil unrest in many countries. War and unrest in Liberia, Sierra Leone, Mali, Nigeria, Zaire, Sudan, Ethiopia, Somalia, Rwanda, Mozambique, and Angola have produced large numbers of refugees. In Southern Africa the devastating drought reduced grain production by 50% in 1991/92 and transformed the area into a major cereal-deficient zone.

The natural environment continues to deteriorate in the face of relentlessly high population growth. AIDS has reached epidemic proportions in several countries and threatens to reverse the considerable progress in health over the past three decades. Some countries, particularly Kenya, Zimbabwe, and Botswana, may have reached their demographic inflection points, but total fertility rate (TFR) for SSA has remained at 6.5 for the past 25 years compared with 4 for all developing countries together (Cleaver and Schreiber 1992).[5] There is evidence that portions of the populations, particularly in urban areas, are responding to family planning efforts, but this has not yet translated into a widespread demand for fewer children.

SSA has lost ground and neglected opportunities to maintain and strengthen traditional areas of economic growth (traditional exports), as well as develop new markets. By encouraging dependence on food imports, trade policies of developed countries, especially the European Community's Common Agricultural Policy, have generally not served SSA's longer-term interests.

International markets are becoming increasingly competitive and, in a growing number of communities and entire countries, it is not immediately evident where a comparative advantage can be found for virtually anything that Africa might produce. The overwhelming thrust of the technological change in progress in the 1990s is likely to work against Africa's competitive position in the production of most commodities. Other areas, including Eastern Europe, Southeast Asia, and Latin America, generally offer international corporations more attractive prospects for investment. From almost every perspective, the region faces the future at a disadvantage compared to most of

5. The total fertility rate (TFR) is the total number of children the average woman has in a lifetime.

the developing world.

Despite considerable negatives, some indicators suggest that economies in a number of countries are responding to major doses of structural reform. Capital output ratios have improved as existing manufacturing capacities are more fully utilized. Foreign exchange and inflation are being brought under control and some of the more abusive economic policies have been adjusted (Wolgin 1990). A profound demand for political change is evident throughout the continent, particularly in countries ruled by long-standing, one-party systems or military regimes.

Donor strategies for SSA are once again in transition. There is a noticeable turning away from marginal areas and equity concerns in favor of searching for comparative advantage. Structural reforms have reduced real wage rates, which should open up new possibilities.[6] Donors, particularly USAID, have sought to encourage private business and investment.

For the most part, major policy reform decisions have already been made. The challenge now is to get their ramifications to filter down to the operational level of private businesses. The embryonic private sector is seen as the development motor of the future, but mistrust and lack of experience are only gradually giving way to positive cooperation between government and business.

The shift in attention to the private sector has led to a dramatic expansion in the activities of both external and indigenous NGOs operating in the region. This expansion has strained the capacities of many NGOs and risks moving the focus away from client-driven agendas to defining problems in terms of what individual organizations are equipped to do.

Most donors have included improvements in natural resource management and environmental conservation to their current strategies. Tourism has considerable potential, but the continued health of this industry is strongly tied to peace, economic stability, and dramatic improvements in efforts to conserve the environment.

USAID and the World Bank are reexamining their respective approaches to supporting agricultural research and development in SSA. The concerns about NARS in particular led to the creation of the Special Program for African Agricultural Research (SPAAR) in 1985 (SPAAR 1987). Since 1990 two major regional planning efforts sponsored by SPAAR have been completed for the Sahel and Southern Africa. The resulting Frameworks for Action are providing guidance for support of reforms in NARS and the growth of regional and subregional collaboration involving NARS, IARCS, and regional institutions based upon comparative advantage. If successful, these efforts could lay the foundation for the needed improvements in the productivity of the research services and the flow of adoptable innovations to farmers.

Concerns about the performance of the agricultural sector and the contribution of research have given rise to the current set of impact studies. The MARIA study results indicate that much more is happening than was imagined, and a great deal of it is positive. In addition, the experiences of maize illustrate the considerable potential of agricultural research to produce widespread improvements in productivity. Increasing productivity is clearly the key to reversing negative trends and establishing (or reestablishing) the region's comparative advantage in the provision of goods and services. Improvements in factor productivity for agriculture in particular is critical in terms of shifting resources away from meeting subsistence needs, toward producing for sale and investing in the future, including education and conservation of the environment.

These changes are taking place against a backdrop of growing competition for limited donor funds in which SSA will do well to maintain net flows at current levels. The prospects of

6. Many economies, however, continue to manifest symptoms of full employment while labor productivity remains low. Reversing these conditions may be the key to continued progress with economic reforms.

having to do more with less seems an insurmountable challenge. However, the government-led strategies which, in various guises, have dominated development policies for three decades, were among the major consumers of funds. The challenge is to find viable alternatives to these largely discredited efforts at least as much as securing the funds to support them. Success in this area is vital to sustaining the movement toward political change and avoiding yet another round of failed expectations.

MAIZE[7]

Maize was probably introduced to Africa in the 16th century by the Portuguese as a means to provision the slave trade (Miracle 1986). Although maize was eventually grown in every country on the continent, very little research was done on it before the 1950s–60s when most European colonies in Africa became independent. The exceptions were in South Africa, the Rhodesias (Zimbabwe and Zambia) and Kenya, where maize was the major staple. The settler communities in these countries grew it on a commercial basis, creating a demand for research and establishing the input and crop marketing infrastructures that helped put research results to immediate use. In the early 1960s these were the first countries to cross high-yielding Latin American maizes with local varieties, and the first to breed and distribute hybrids. In the nonsettler areas the emphasis of agricultural research was still on cash crops for export. In most African farming systems maize was a vegetable garden crop, eaten green; only in East and Southern Africa was it grown as a field crop and dried and milled.

This study focuses on maize because its story promised useful lessons could be learned from the following perceptions: (1) in some places spectacular improvements in performance emerged from crossing local varieties with high-yielding Latin American varieties; (2) international research institutes have played a prominent role in the success of maize, as has donor funding; (3) the potential performance of improved maize varieties interested African governments enough to encourage investment in agricultural research; and (4) food production and food security improved substantially in certain countries.

This maize study seeks to better assess the magnitude and the nature of the impacts that underlie these developments. Further, the study is designed to indicate the character and importance of the various factors that have contributed to, or constrained improvements in, maize production and productivity.

Innovations for Maize

The principal types of innovations for maize in SSA fall into two major categories: biotechnical innovations, including germplasm improvement, crop management, and postharvest techniques; and socioeconomic innovations, including improvements in input supply, marketing, and processing. The MARIA study has focused primarily upon biotechnical innovations (technologies) including germplasm, mechanization (notably animal traction), soil fertility management, water management, pest management, and assorted agronomic and postharvest techniques that are the major products of research institutions.

The extent of adoption or demand for an innovation and hence the impacts are largely a function of how well it fits in the target farming systems and alleviates constraints or exploits areas of opportunity (Perrin et al. 1976). Use of the innovation should be consistent with the resource endowments, taste preferences, and aspirations of the farm families who are the intended users, and with the realities of existing policies and input supply arrangements. Often

7. For a comprehensive review of maize research and production trends in Africa see *1989/90 CIMMYT World Maize Facts and Trends: Realizing the Potential of Maize in Sub-Saharan Africa* (CIMMYT 1990).

this has not been the case, and the difficulties are sometimes traceable to the initial definition of research themes and assessment criteria by the research services.

A key area of debate among practitioners of agricultural R&D in SSA has been finding the balance between adjusting the technology to fit the socioeconomic environment and changing the environment to better exploit the technology. Historically, the latter orientation has prevailed. In the past 15 years, however, limited progress in the adoption of innovations outside high-potential areas, as well as growing doubts about the ease of adjusting the socioeconomic environment, has led to a shift toward the former orientation. This shift became a guiding principle of the FSR movement, and is currently reflected in the subjects being pursued in maize research. More recently, criteria has shifted further to encompass a broad range of environmental and resource management concerns (Posner and Gilbert 1991).

The discussion on research themes and criteria has centered on four issues:

1. *Criteria:* Emphasis on maximizing yields under high input and management conditions as opposed to yield stability; resistance to pests and stress; storage, processing, and consumption characteristics; and suitability to a range of farming systems "niches."[8]
2. *Environments:* Emphasis on high-potential areas versus marginal areas.
3. *Disciplinary or subject-matter focus:* Relative importance of breeding versus other disciplines in addressing problems.
4. *Germplasm type:* Hybrids versus exotic OPVs (synthetics and composites) versus upgraded local cultivars.

The results of debates on these issues has profoundly influenced the conduct of maize research in each of the case-study countries and the region as a whole. The identified problems and the resulting research themes for each country are summarized in Table 2.1.

The appropriateness of these themes and their associated criteria are discussed in the case studies and in Annex C (Innovations). In general, there has been considerable progress in adjusting themes and criteria to reflect the realities of the target farming system(s). There are a few examples where the technologies have been produced in response to these adjustments, most notably in the case of MSV-resistant varieties. More account is being taken of what farmers want, and this should be reflected in research results in the 1990s.

STUDY HYPOTHESES

The selection of maize as the commodity for the research impact assessment reflects the belief that innovations for the crop have made significant and measurable contributions to production and factor productivity in the SSA region. Improvements, primarily in the form of increases in maize production, have in turn positively influenced domestic availability of grain, food security, consumption levels, trade balances, and economic growth.[9] This perception constitutes the central hypothesis of the MARIA study. The following list of points can be regarded as subhypotheses designed to define the character and magnitude of the changes in production and productivity.

1. The magnitude and character (e.g., relative importance of yield and area changes) of improvements in maize production and factor productivity are functions of the

8. This would include the production of improved varieties and hybrids with a range of maturities.

9. There is clearly a trade-off between improvement in domestic consumption on the one hand and trade balances on the other. The hypothesis is that a combination of both has occurred, with increases in domestic production translating into i) increases in rural consumption; and ii) reduction of what would otherwise have had to be imported to feed urban areas.

Table 2.1. Maize Research Themes in Case-Study Countries

	Problem / Issue	*Research Themes*
Kenya	■ land security ■ different ecologies and farm sizes (commercial and smallholders)	■ improve yields and crop management ■ target breeding innovations for different altitudes / resource endowments
Malawi	■ poverty, food needs ■ land scarcity ■ on-farm storage and poor processing methods ■ fertility / erosion ■ mediocre response to NPK	■ develop HYVs and hybrids ■ screen for pest resistance flintiness ■ alley cropping ■ micronutrient responses farm
Nigeria	■ broad range of ecologies ■ disease problems, especially in humid zones ■ preferences on color, processing ■ macro/micro nutrient difficiencies	■ target research to different recommendations domains ■ breed for resistance ■ develop white, flinty varieties ■ develop fertilizer recommendations for different ecologies
Senegal	■ food deficits ■ variety of ecologies	■ improve yields ■ screen varieties for each region
Zaire	■ transport, input supply unreliable ■ labor constraints ■ unevenly functioning institutions ■ escalating imports	■ improve roads / markets ■ develop OPVs with good performance under low management and inputs ■ increase yields / areas

commodity's importance in agricultural production. The impacts have been greatest where maize is the dominant staple food.

2. Innovations for maize have positively affected the competitive position of the commodity vis-à-vis other activities. Much of the consequent expansion in maize cultivation has been at the expense of other farming enterprises.
3. On an individual basis, the principal beneficiaries of maize research have been farm families in well-endowed (soil and water conditions) areas, and larger, commercial maize producers. However, many small, low-resource farmers have also benefitted.
4. Increases in maize production have been the greatest where institutions concerned with research and development of the commodity have functioned well. Impact is a function of the rate and degree of adoption which, in turn, is related to (i) the effectiveness of research/extension linkages; (ii)

access to inputs; (iii) the effectiveness of extension; and (iv) skill in targeting research themes to client groups.

5. A favorable policy environment, particularly with regard to the accessibility and prices of inputs and output marketing policies, and the general conditions in a country (macroeconomic and political) are critically important in explaining the magnitude of adoption and impact of maize productivity-increasing innovations.
6. The performance of national maize research programs is a function of adequate financial and human resources and the quality of their management.
7. External institutions are critically important in explaining progress in the development and dissemination of innovations for maize in the region.[10]

Although the limitations of data, time, and resources available for the MARIA study constrained the extent to which the above hypotheses could be formally addressed, these issues were examined in the case studies and the results are reviewed in Chapter 3. Chapter 5 (Conclusions) summarizes the findings with respect to these hypotheses across the case studies, and also draws upon experiences in other countries. The lessons from the study, in turn, build upon the findings with respect to the above issues.

10. In using the term "External Institution," we are refering to a range of institutions, including IARCs, regional research institutions, and donor-supported projects.

3. Country Perspectives

The changes in maize production and productivity in sub-Saharan Africa over the past 25 years represent an aggregation of the experiences of 40 countries; hundreds of provinces, districts, and project areas within those countries; and thousands of villages. At the base, millions of farm families have been exposed in varying degrees to innovations associated with maize and a large percentage have made adjustments in their farming systems to selectively accommodate improvements. Each farm family is unique in the changes in allocations of land, labor, and capital it makes in response to new conditions and information. Regional, subregional, and even country-level aggregations not only fail to capture the diversity of responses, but can seriously obscure any change by averaging movements in area and yields in opposite directions.

In an effort to illustrate this diversity, the MARIA study utilizes a case-study approach to examine impacts from maize innovations at the farm, district or project area, and country levels. The focus is also on the changes in productivity and shifts in resource allocations that farm families did or did not experience as a consequence of agricultural innovations. Germplasm is emphasized since varietal improvement is most easily associated with research on maize. Other innovations such as animal traction are also important in explaining productivity changes.

This chapter summarizes the impacts and factors associated with changes in techniques for maize production and postharvest practices for the five main case-study countries of Kenya, Malawi, Nigeria, Senegal, and Zaire. These five countries include a cross section of regions, ecological zones, and farming systems; their characteristics, including the nature of national increases in maize production, are presented in Tables 3.1 and 3.2.

The chapter consists of five sections, each of which summarizes the major findings from an individual country study. The complete country studies are also being issued as separate reports specifically for use by the countries involved. The summaries necessarily focus upon the most salient points related to the impacts and factors. Each section begins with an overview of the major factors, including research, extension, policies, ecological conditions, and the character of the farming systems that collectively influenced the development, dissemination, and adoption of innovations for maize. The main body of each section reviews the impacts associated with changes in maize production and productivity at the farm, project or province, and country levels. Chapter 4 examines the aggregate impacts at the subregional levels, and places the country studies in a broader context. The principal conclusions and lessons learned in comparing the experiences of different countries and subregions are presented in Chapters 5 and 6 respectively.

Neither the country summaries or the complete case studies are intended to be comprehensive reviews of the maize subsectors in these five countries. Rather, the focus is on specific areas and time frames in which innovations for maize were identified and promoted. Each country contains considerable diversity in farming systems, including the importance of maize. For the MARIA study, this diversity is illustrated in large part by cross-country comparisons, rather than attempting to cover the complete range of conditions and experiences in individual countries.

Table 3.1. MARIA Case-Study Countries

Country	Population (millions)	Maize Area (000 ha)	Maize Production (MT)	Calories / Cap. / Day Number	Calories / Cap. / Day % total
Kenya	25.2	1,768	2,757	1,030	48
Malawi	9.4	1,234	1,334	1,419	66
Nigeria	122.5	2,000	1,904	146	7
Senegal	7.5	106	123	149	7
Zaire	37.8	873	750	190	9

Source: USDA/ERS.

Table 3.2. Average Annual Growth Rate, Maize Area, Yield, and Production, 1966-88* (by country)

Country	Area %	Yield %	Production %
Kenya	1.87	1.15	3.04
Malawi	1.04	- 0.18	0.85
Nigeria	2.56	0.00	2.56
Senegal	3.43	2.07	5.60
Zaire	2.16	2.17	4.38

*Five-year moving average.

Source: USDA/ERS.

KENYA[1]

Kenya has seen a spectacular growth in maize during the past 50 years. From being a newly imported, ill-suited crop at the beginning of the century, it has become the dominant staple food of Kenyans country-wide. Institutionalized maize research began in Kenya in the 1940s. Widespread success was achieved in the 1950s and 1960s with the development and release of hybrids that offered a minimum of 30% increases in yields in the wet highlands of western Kenya. This progress was associated with large-scale commercial farming, relatively stable political conditions, and favorable agricultural policies that supported research, inputs, and extension services. The success of hybrids has been well documented, therefore the case study has chosen to focus on the impacts of drought-evading maize innovations that were developed outside the commercial maize area, at the Katumani station in Machakos District from

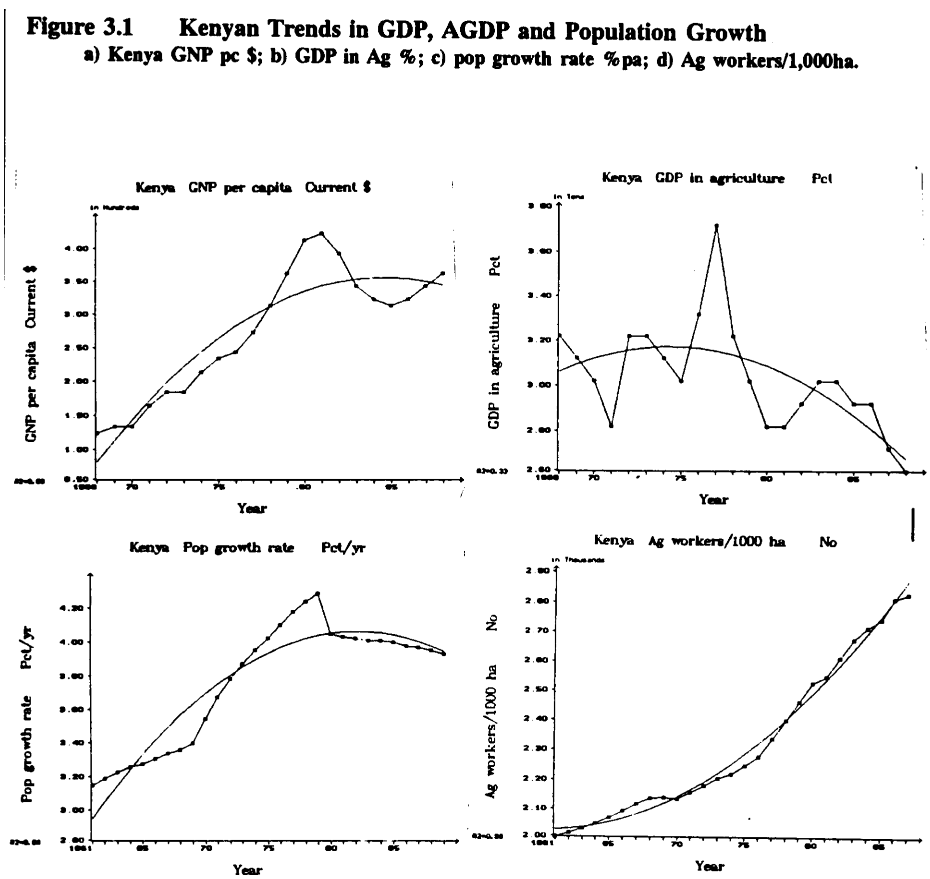
1. This section is a summary of the MARIA case study for Kenya prepared by Marie-Therese Sarch and Elon Gilbert.

1957 to 1970. The case study also highlights contrasts with the story of hybrids in western Kenya, and concludes with a review of national- level impacts from maize research.

Agriculture is the largest sector of Kenya's economy and provides nearly all the country's food requirements. It has played an important role in the impressive growth of Kenya's Gross Domestic Product (GDP) (Johnston 1989). In the three decades since independence, GDP grew at almost 2% a year over an annual population growth rate of 4% (World Bank 1987) (Figure 3.1a). Since 1976, however, agriculture has accounted for a decreasing proportion of GDP (Figure 3.1b). This is partly explained by lower world prices for export crops and reduced government financial support for commercial agriculture. Despite these drawbacks, the sector continues to be the source of 60- 70% of total export earnings; 75% of total employment; livelihoods for 85% of the population of 23 million (Karanja 1990); and has been able to feed one of the fastest growing populations in the world. Although the rate of increase may now be slowing, population growth and increasing land pressure have resulted in outmigration from high-potential areas to the arid and semiarid zones (Figures 3.1c & d).

Maize is the most important food crop in Kenya. It is the staple food for over 90% of the population and accounts for over 40% of the total dietary intake of an average Kenyan

Figure 3.1. Kenyan Trends in GDP, AGDP, and Population Growth
a) Kenya GNP pc $; b) GDP in Ag %; c) pop growth rate; d) Ag workers/1,000 ha



Source: See Annex D.

(Blackie 1989). The area planted with maize has increased from 1.2 million ha in the late 1960s to 1.8 million ha in the late 1980s (ERS, USDA 1989), and production has increased from 1.5 to 2.8 million MT. Kenya has a comparative advantage in growing its own maize, but as transport costs are half the fob price and double the cif price, it is normally not worth exporting or importing maize grain. Preliminary indications for the current year (1992/93) are that the country is moving strongly into a deficit position and will require large and growing imports without a major upward shift in domestic production.

Overview of Factors

Agricultural Sector

Kenya has a land area of 575,000 km2 and a wide range of ecological and climatic conditions (Figure 3.2). Only 19% of the total area is classified as high and medium potential; another 9% is arable, but subject to periodic drought. Most of the remaining area is suitable for grazing, or is desert. Population density on arable land varies from 340 per km2 in the high- potential areas in the west, to a national average figure of 195 per km2. Population density is highest in areas of abundant rainfall, but a large majority of people live in medium to low-potential zones receiving less than 1250 mm rainfall per year.

At the turn of the century, the high-potential areas of western Kenya were settled by Europeans who established large, commercial farms. A major change since independence and the Swynnerton Plan has been the decline of large-scale farming.[2] In 1958, large farms produced 80% of marketed output; now they account for less than half (Migot-Adhallo 1984) and only a quarter of total agricultural production (Ndambuki 1987). Large mixed farms produce maize, wheat, barley, and livestock products. Estates produce 30% of coffee and 65% of the tea as well as other horticultural crops (World Bank 1989a).

Small farms are defined as less than 8 ha but are usually (75% in 1979) less than 2 ha. In 1974, three- quarters of small holdings were concentrated in the medium- and lower-potential areas of Eastern, Central, and Nyanza Provinces (1974-5, 1978-9 Integrated Rural Surveys, ODA 1982). In 1989, smallholders produced 75% of total agricultural output and just over half of marketed output while using 66% of the arable land and 85% of the agricultural labor force. Most smallholders combine food crop and livestock production with some cash cropping (cotton, tea, coffee, pyrethrum, or sugarcane depending on the area). Smallholders range from prosperous tea and coffee growers to subsistence farmers who represent a quarter of all smallholders. Between 25 and 45% of small holdings are headed by women (World Bank 1989a).

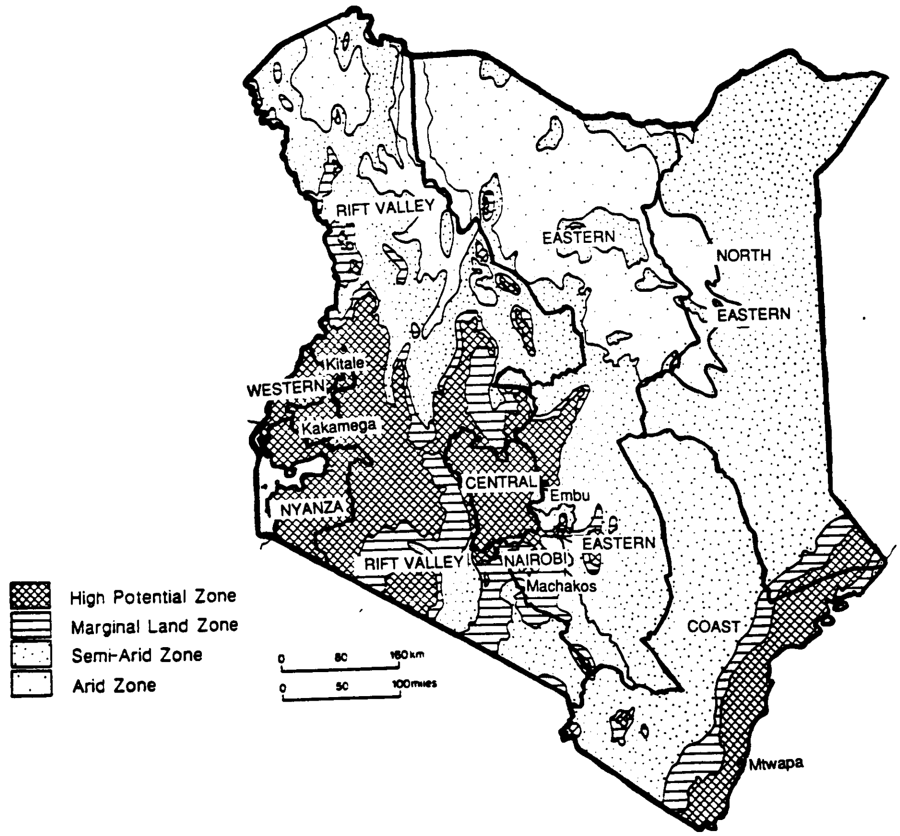
Maize is grown in almost all the agroecological zones in the country and currently occupies a quarter of the cropped area. Small farm maize production increased from 61% in 1976/77 to 81% in 1981/82 (Akello-Ogutu 1986). Most of the maize produced on small holdings is consumed on-farm; approximately 20% of total small- scale production is sold. In contrast, large farms sell 75% of their maize production that they produce on 3% of the national maize area. (Ndambuki 1987)

Farming Systems in Machakos

Machakos District lies within the Eastern Province, southeast of Nairobi. Most of the district falls within semiarid, agroclimatic zones, although there is significant variation in land potential. The most arid areas are the low-lying

2. In 1954, the Swynnerton plan to intensify the development of African agriculture in Kenya was responsible for an impressive expansion of export crops. The plan provided for the consolidation and registration of land holdings and aimed to give farmers security of tenure and incentives to maintain soil fertility and prevent erosion.

Figure 3.2. Administrative Map of Kenya Showing Ecological Potential



south and southeast parts of the District.

Machakos is peopled by the Akamba tribe who numbered approximately 1.5 million in 1988 and represented 6.5% of the national total. Average density is 78 persons per km2, reaching over 300/km2 in higher-potential areas. The growth rate is very high (3.9%) and is a major force of change, highlighting the need to find new ways of retaining and improving land productivity (ODI 1992e, 1992g).

Urban population growth in the District increased from 2% in 1962 to 6% in 1979, indicating a shift to nonfarm activities, but the majority of people in Machakos are smallholders who continue to earn their living primarily from agriculture. Cultivation accounts for 80% of land use. Maize and pulses dominate farming systems and are cropped and intercropped on 70 to 90% of cultivated areas, depending on the agroecological zone. Although cash crops occupy a much smaller part of farmland, they are an important source of income and off-farm employment for many households. In the high-potential areas coffee is an important cash crop and, during the 1980s, fruit and vegetable crops showed an upward trend (ODI 1992e).

There is great year-to-year variation in agricultural output and incomes that is caused by erratic rainfall patterns. Despite the large proportion of cultivated area devoted to food crops, in times of drought the District has depended on food imports, especially maize grain and maize meal. On average, however, maize imports per capita have decreased over time, indicating that food production has improved in relation to requirements.

Maize Research[3]

Agricultural priorities are both reflected in, and facilitated by, the institutional framework that exists in Kenya. The Kenya Agricultural Research Institute (KARI) is formed around 14 national research stations and 11 regional stations situated to cover the foci of major crops, land use, or ecological conditions (Wang'ati 1983). Although KARI does not currently come under the auspices of the Ministry of Agriculture (MOA), the regional research stations that it encompasses were set up as part of MOA before independence and later were hived off to become KARI. The national research center for maize is based at Kitale in the high- potential, high-altitude area of western Kenya. Regional stations are based in coastal Mtwapa, medium-altitude Embu, and at Katumani in semiarid Machakos District.

A number of national and external agencies are also concerned with maize research in Kenya, including input companies, universities, and IARCs. The Kenya Seed Company (KSC) has had an active breeding program for more than decade and tests materials throughout the country. CIMMYT had an East-Africa regional office in Nairobi, and the four Kenyan universities perform some maize research. These activities have not been well coordinated in recent years and, overall, the Kenya agricultural research program has been suffering from serious structural and programming weaknesses (USAID 1986).

<u>Breeding</u>

In 1955, a systematic maize improvement program was started in the commercial farming areas of western Kenya, at Kitale. Michael Harrison was appointed to develop late-maturity maize hybrids suitable for the commercial, European, maize-growing regions that received up to 2000 mm of rainfall 6 to 8 months of the year. Harrison crossed local, well-adapted varieties with Latin American germplasm and, between 1964 and 1989, the Kitale program working with the Kenya Seed Company (KSC), developed and released 11 high-altitude maize hybrids that out-yielded farmers' maize by at least 30%. By 1973, 70% of all farmers, including smallholders, were using hybrids throughout the region (Gerhart 1975).

Over the same period, maize improvement efforts were expanded to develop varieties suited to different agroclimatic zones as follows (Karanja 1990):

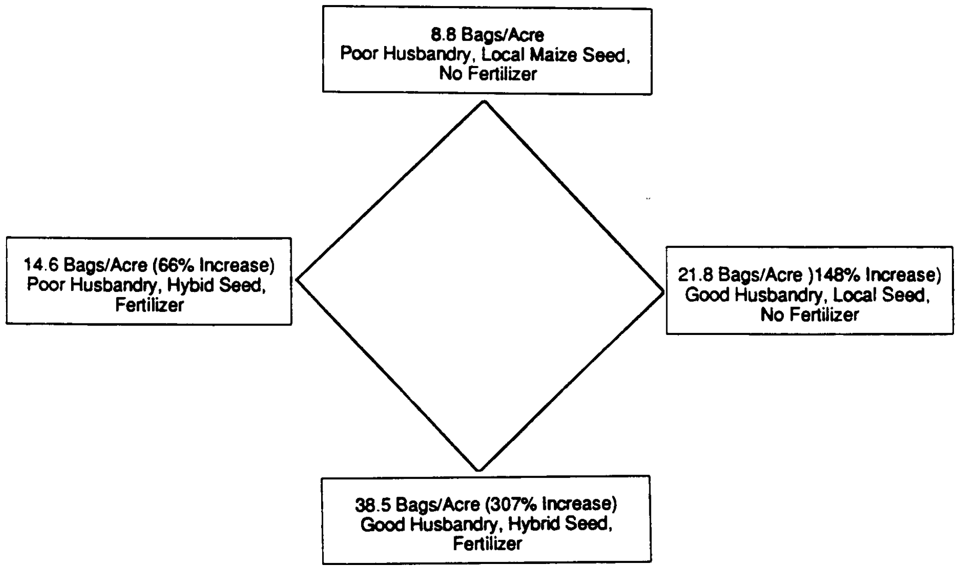
- Maize improvement for the medium-rainfall, low- altitude tropical regions had begun on a small scale at the Coastal Research Station, Mtwapa, in 1952. Short- season varieties were screened for resistance to leaf-rust (Puccina Poysora). A Coastal Composite (CC) was released in 1974, but was not widely adopted by farmers because of its low yield and yellow color. Pwani Hybrid I (PHI) was released in 1989 by KSC with a 5 to 15% yield advantage over CC and earlier maturity.
- Maize breeding in Machakos began with Brian Dowker's program for early maturity at the Katumani Station. Katumani Composite B (KCB), which flowered within 65 days, was released in 1966.
- Research on medium-maturity maize was started at Embu Station in 1965. A cross between Kitale late-maturity hybrids and early-maturity KCB led to the release of H511, a hybrid with a yield advantage of 36% over local "Muratha" maize.

<u>Agronomy</u>

In 1963, Allister Allan initiated a systematic agronomy program with breeder Michael Harrison at Kitale. Through evaluating new hybrids over a wide range of conditions, district

3. Additional discussion of maize research in Western Kenya and the comparison between areas is included int he formal country case study.

Figure 3.3. Allan's Maize Diamond
(1 bag per acre = 0.23 MT per hectare)



Source: Allan (1969).

husbandry trials found that, under better management, yields from local maize were double what had previously been thought: "Clearly hybrids were not the only factor needed to raise national yield levels." (Harrison 1970: 47).

In order to determine objectively the interactions between agronomic factors and genotype, Allan designed a series of 26 factorial district maize husbandry trials. Each of six factors (time of planting, plant population, genotype, amount of weeding, and phosphate and nitrogen application rates) were considered at two levels: a "high" level representing recommended practice; and a "low" level corresponding to farmers' practices. Time of planting and genotype were found to be the most important factors in explaining farmers' low yields (Figure 3.3). "Allan's Diamond," as it came to be known, played an important role in communicating the benefits of hybrids and improved crop management.

Functioning of Research and Development

By the end of the 1960s many maize researchers agreed that average maize yields had "...increased greatly in many areas since 1964 because of a determined effort to improve the levels of all the important factors simultaneously" (Harrison et al. 1968). These factors included effective breeding and agronomic research programs; an active field extension service; a commercial seed firm (KSC) providing seeds at reasonable prices; and a well-coordinated effort through all stages of the research and technology transfer.

The maize research program functioned efficiently in its early days (Allan 1992; Harrison 1992). Small numbers of long-term staff facilitated communication within and between the research service, the extension service, and commercial farmers who played an active role in setting research agendas. Coordination was facilitated by the fact that research and extension shared the same ministry (MOA), which is no longer the case. KSC continues to play an important role in breeding and distributing improved germplasm.

Recent increases in productivity compare poorly with the leaps that were made during the early 1970s. The quasistagnation of national maize yields since 1976 is associated with difficulties in the National Maize Research Program. Since 1976, only six new varieties have been released, whereas in the 15 years before 1976, 21 new releases were made.[4] This is explained by several factors: the yield advantages that were offered by early releases are not repeatable; they were "the cream to be skimmed off the milk." In addition, there has been an increasing imbalance in the allocation of research funds to the point where staff salaries account for more than 90% of the current budget, leaving little to support research activities. With the decreasing value of salaries, staff are both less able and less motivated to conduct trials (Allan 1992; Harrison 1992).

Government Policy

In contrast to many of the other newly independent nations of SSA, in the 1960s Kenya hosted a policy environment that favored agriculture. The European settlers of the colonial era had received considerable government assistance, and their success served to sustain government support of the sector. Since independence, government policy has touched almost all aspects of maize production. Agricultural research, particularly for maize, continues to be regarded as a primary source of increases in maize production (World Bank 1989a). Until 1979, agricultural policy favored commercial maize producers through Guaranteed Minimum Returns and the Large Farm Credit Program. After these policies were removed, the government relied on fertilizer pricing and the parastatal marketing board to secure national food supplies. Fertilizer pricing policy has recently been relaxed, and the government attempts to control maize supply and prices through the marketing board alone.

The National Cereal and Produce Board (NCPB) was established in 1979 by merging the former Maize Marketing Board with the Wheat Marketing Board. As with its predecessors, the NCPB is charged with the purchasing, handling, and storage of all grains nationwide. Government policy states that all maize, unless sold directly to the consumer, should be marketed through the NCPB, which sets producer and consumer prices in order to stabilize the flow of maize to the consumer and protect farm incomes. The policy is designed to force sales of surplus to the NCPB, which relies on official restriction of interdistrict movements of maize to two bags (0.2 MT) without a license. These restrictions have exaggerated both interdistrict and producer-consumer price differentials, which in turn has stimulated an illegal parallel market into which most smallholder maize is sold (Akello-Oguto, 1986).

Impacts in Machakos District

In Machakos, the challenge was to develop drought- evading and drought-tolerant varieties to cope with the low rainfall that fell in two erratic seasons. The rainy seasons vary in length from 50 to 70 days, but the local Machakos White maize took 76 to 78 days to flower, which was barely enough for a successful maize crop in a normal year (ODI 1992a). Originally, it was planned that Katumani would work on drought-tolerant sorghums and millets. However, Brian Dowker found that, in most years, there was continuous soil moisture for 60 days so he initiated maize research on early- maturing varieties. Katumani Composite B (KCB) was released in 1967 (Table 3.3). The variety takes 65 days to flower and yields 3-4 MT/ha, an improvement on the average 2.5 MT/ha offered by previous releases and more reliable

4. Since 1976, KSC has also released an additional two varieties.

Table 3.3. Achievements at Katumani

Variety	Year released	Days to 50% silk	Yield (tons/ha)
Machakos White	—	77	1.8 - 4.0
Taboran	1961	63	1.83
Katumani			
Synthetic II	1963	65	2.66
Composite A	1966	65	2.82
Composite B	1968	65	3.0 - 4.0
Makueni Composite	1969	55	2.5 - 3.5

Source: National Dryland Farming Research Station.

than the 1.8 to 4.0 MT/ha obtained from Machakos White.

Dowker and Hugh Bennison also conducted agronomic research at Katumani over the same time period. They found that (i) early planting was critical; maize yields decreased by 5% for every day that planting was delayed (Dowker 1964); and (ii) the place in a rotation had a significant nitrate effect on yields of Katumani varieties—yields were best after a fallow and worst after a local maize variety (Bennison and Evans 1968).

Impacts on the Allocation and Returns to Resources

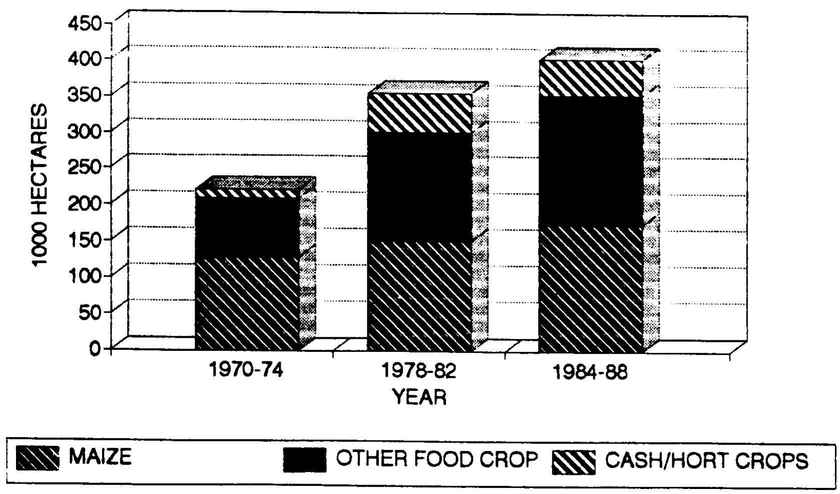
A major change in the farming system of Machakos district has been the increase in the area cultivated (Figure 3.4). As in the rest of Kenya, Machakos has seen an expansion in the area of maize both at the expense of previously uncultivated, semiarid grazing land, and areas previously devoted to sorghum and millets. Maize is preferred because it is easy to grow, less susceptible to disease than sorghum, and requires less labor for bird scaring.

In 1930, maize was estimated to occupy 42% of the cropped area, and sorghum and the millets together only 21% (Lynam 1978). The latter figure declined to 10% in 1960 and 2% in 1970, representing 2100 ha of sorghum compared to the 137,500 ha of maize that was cultivated in 1970. In 1990, it was estimated that 80% of farmed land was allocated to maize and pulses, some of which is put to maize as a sole crop and the rest to a maize and pulses intercrop (ODI 1992e). The land allocated to maize increased from 1930 to 1970 and remained relatively stable (increasing absolutely, although decreasing in relation to other crops) for the last two decades (Figure 3.4). In 1970, Harrison estimated that half the maize area was planted to Katumani varieties.

Land scarcity was not a problem in Machakos between 1960 and 1980, although it is now (ODI 1992e). The combination of land pressures and early-maturing varieties (KCB) facilitated the expansion of maize cultivation into the semiarid areas of the district.

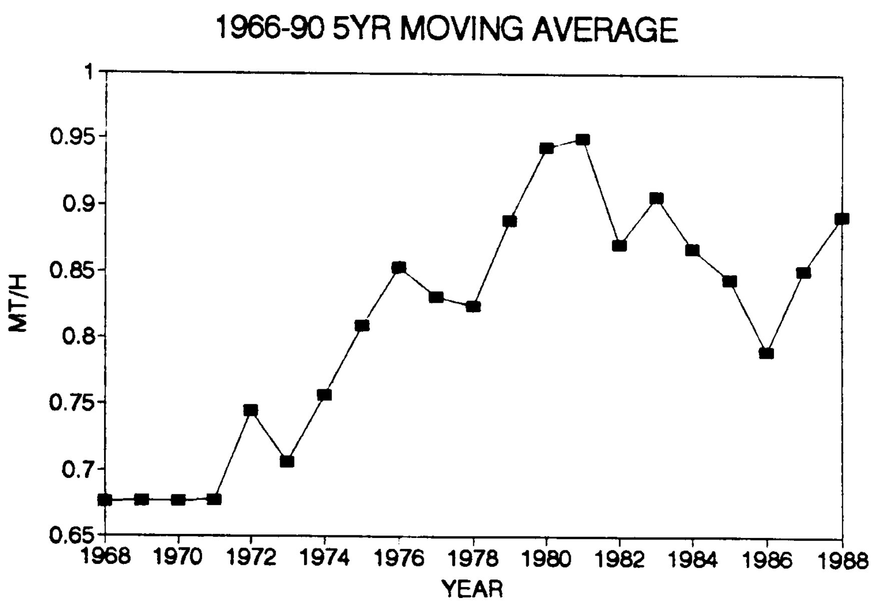
The expected impact from KCB's adoption is reduced yield depression due to bad rainfall, rather than increased yields in good years. Thus, increased use of drought-evading maize should result in higher average yields over a period of years. Due to KCB's adoption and improved land conservation measures (e.g., terracing) yields have increased despite several severe droughts and the expansion onto lower-potential land (Figure 3.5). Recent trends, however, show a decline in both yields and cultivated

Figure 3.4. Cropping Patterns in Machakos, 1970-1988



Source: ODI (1992e).

Figure 3.5. Yields of Maize in Machakos, 1966-1990



Source: ODI (1992e).

area planted to maize. This may be the result of a combination of factors including the degradation of land over time; the erosion of KCB's early-maturity advantage through crosses with local varieties; and possibly by farmers selecting the largest cobs for seed, which will also be the latest-maturing cobs. As the early-maturity advantage is lost the plants do not reach their growth potential before the rains stop. Changes in cropping patterns (i.e., less land planted to maize) are likely to be a response to these, among other factors.

Capital

A comparison of studies based on interviews with farmers in low-potential areas in the 1960s (Heyer 1967) and the 1990s (ODI 1992e) show that increased levels of both fixed (terracing, plough oxen) and working (manure) capital are required for maintaining soil fertility and preventing soil degradation. The expansion of cropping into the previously uncultivated, low-potential areas of the District underlines the importance of investing in the soil. Katumani varieties have facilitated this expansion and contributed to increased capital requirements for these areas. However, the expansion may also have been influenced by the Department of Agriculture's earlier research into restoring dead grazing land to a productive condition (Pereira and Beckley 1952; Pereira et al. 1961, cited in ODI 1992i), and the subsequent soil and water conservation research at Katumani. Increased capital requirements may be a consequence of this research as well.

Since KCB is a composite, annual seed purchases are not essential and the majority of farmers use their own seed from the previous harvest. Thus, adoption of Katumani varieties requires little extra capital. However, agronomic recommendations for early planting appear to be associated with increased use of animal traction[5] and the belief that rains will fall as expected. Katumani varieties have helped farmers increase their range of options, thus strengthening their flexibility in coping with the risks of maize production. There is evidence that returns to capital have increased since the introduction of Katumani varieties, although it is difficult to attribute a specific proportion, or even causality, to maize research (Rukandema et al. 1981; ODI 1992b).

5. Plough ownership has risen from 1% to 62% of farmers in some areas of the District (ODI 1992e).

Labor

The trends in cropping patterns since 1970 suggest that the proportion of labor devoted to maize has decreased relative to other food crops (Figure 3.4). This may imply that returns to labor in other food crops have increased in relation to those from maize.

There is evidence, however, that the Katumani varieties have facilitated absolute improvements in the returns to labor in maize cultivation. Linear programming demonstrated that a Katumani maize mix would give between 850 and 1180 KSh per man-day on a 6-acre (2.4 ha) farm, whereas without Katumani maize, returns would be between 380 and 880 KSh, depending on the rainfall in that year (Heyer 1967). Increased returns would seem to make sense: Katumani varieties have been assimilated into farmers' systems and are grown alongside local varieties. Although early planting is recommended, farmers do use early-maturing varieties to delay planting. It is probable that the Katumani varieties have not involved more labor than local ones; thus higher yields represent improvements in the productivity of both land and labor. The decreasing proportion of cultivated land devoted to maize may indicate that increased productivity has allowed a shift of resources to other food crops, usually pulses. This shift represents an improvement in diets and/or savings on food purchases.

Impacts on District Incomes

In areas of erratic rainfall, farm incomes can vary significantly from one year to the next. The calculation of farm incomes depends on the prices used to value the subsistence element that can vary according to the degree of scarcity in local markets (ODI 1992b).

Frequent droughts mean that farmers are often food purchasers. Fluctuations in output produce large movements in staple food prices. For example, the price of maize fell by 31% from March to September 1985, but actually increased in the same period in 1987. Prices fluctuate seasonally and over time reflecting the incidence of drought, restrictions on the movement of maize, and seasonality in local supplies.

KCB was intended to improve yields in years of low rainfall and thus contribute to greater stability in maize output, prices, and the maize portion of household incomes. A corollary of this would be stabilized maize prices and that part of farm incomes accounted for by maize production. NCPB, as a buyer of last resort, was specifically designed to do this. Only 12% of maize sales, however, are to the NCPB (Akello-Ogutu and Odihambo 1986) and, as demonstrated above, there are still large fluctuations in maize prices in Machakos.

Food Availability

The adoption of KCB is associated with reduced dependence on food imports into Machakos in the past 30 years. Examination of district trade in maize since the 1940s shows a reduction in average annual imports per capita of more than half (e.g., from 17 kg/annum [1942-62] to 8 kg/annum [1974-85]). Food availability has been improved despite rapid population growth, an expansion of cultivation into the more arid areas, and a substantial increase in the local urban population.[6] Assuming that Machakos residents require 120 kg of maize per capita a year, then district requirements of 180,000 MT have been met (q 5%) in 5 of the 8 years from 1980 through 1988, which included the severe drought years of 1984/85.

The story of maize innovations developed at Katumani in the 1960s has both contrasts and similarities with the impacts of maize research done elsewhere in Kenya.[7] The contrast lies in the fact that researchers specifically followed a different strategy for Katumani by focusing upon yield stability through early maturity to evade drought and sacrificed yield potential in the process. There is similarity in the sense that the maize research programs at Katumani and in other areas of Kenya have suffered from a decline in productivity that started in the 1970s. Katumani is a striking example of adjusting research themes and assessment criteria to better reflect local conditions, but unfortunately this approach was not sustained at Katumani nor was it frequently replicated for other crops and areas. During most of the 1980s, the Maize Research Program at Kitale focused on maximizing yields under good management in high-potential areas with long growing seasons and generally resisted suggestions based on field studies that they might do otherwise.[8]

National-Level Impacts

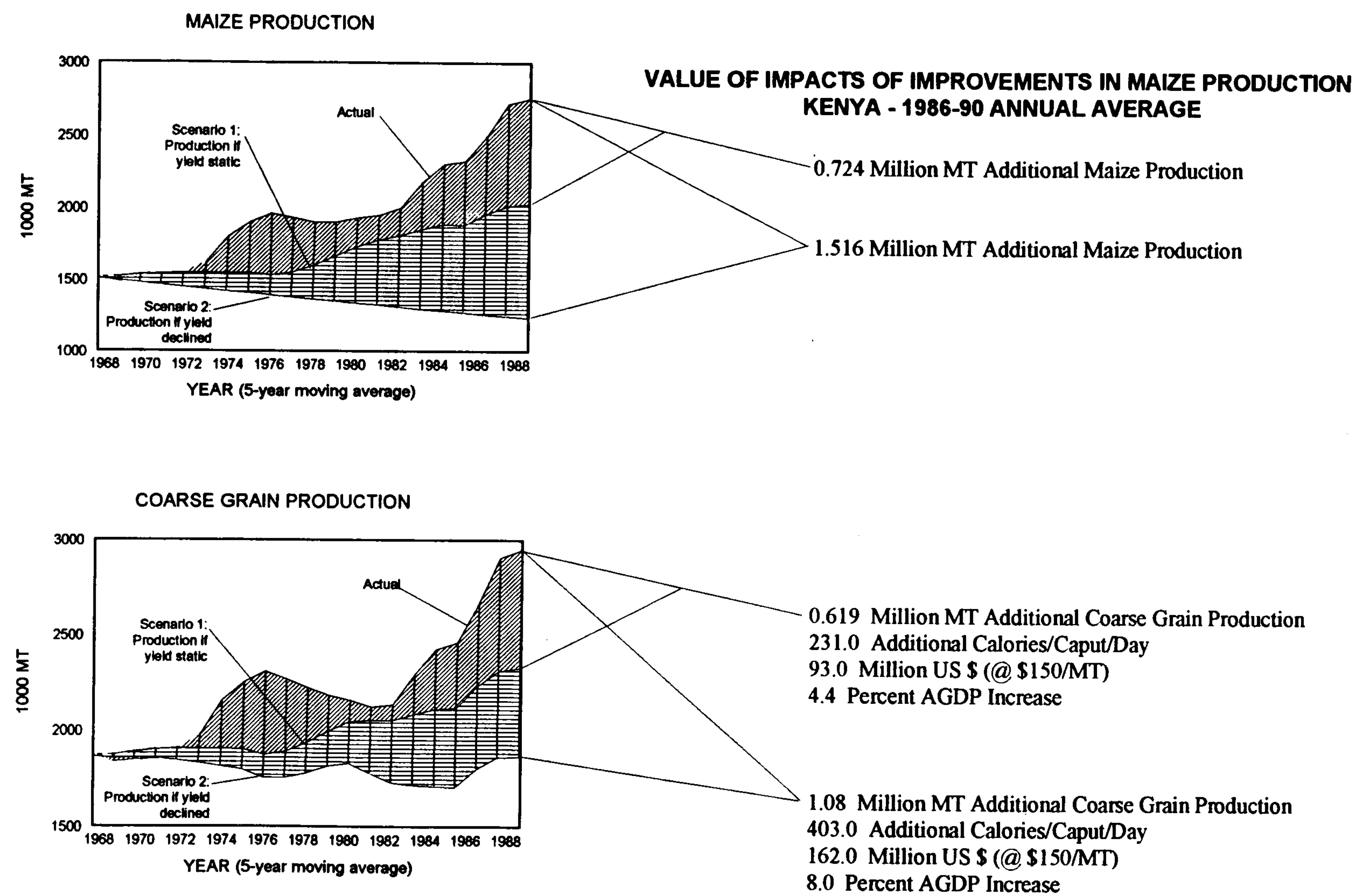
The fivefold increase in national maize production in Kenya over the last 30 years has accommodated a doubling in population over the same period (Karanja 1990). However, after the yield increases of the early 1970s, the growth in production has mainly come from area expansion. Decreasing yields after 1976 are explained by extending maize production into marginal areas, as in the case of Machakos District. By 1985, yields started to increase again and accounted for a significant proportion of the growth of production during the latter part of that decade. During this same period, maize area expanded, but accounted for a decreasing

6. It is possible that, in the second period, more food was imported informally—the figures relate to net exports and imports of the NCPB and its predecessor, and famine relief. The difference between the 1942-62 and the 1974-85 figures, however, is sufficiently great to allow the ODI to conclude that food production in relation to district requirements in the 1980s is better than it was in the 1960s and 1950s, before the introduction of the Katumani maize varieties.

7. The story of Katumani maize research is compared with that of Kitale, Western Kenya, in the full Kenya case study.

8. An example would be the improvement of short--duration cultivars suitable for intercropping and double cropping in the medium- to high-potential areas of Western Kenya (Haugerud and Collinson 1990).

Figure 3.6. Kenya Maize and Total Coarse Grain Production, with and without Technological Change



Source: See Annex D.

portion of total area under cultivation. The shift of maize onto lands with lower potential released the better fields for higher-income crops such as coffee and tea.

Despite the slowing of progress in recent years, the research done in the 1960s has had an important impact. This can be seen by comparing the actual production trends of maize and total coarse grains with what might have happened in the absence of technological change (Figure 3.6). Comparing the actual trend in maize and coarse grain production with the two "without innovations" scenarios suggests that a major portion of the increase is traceable to the adoption of technologies developed by research, and not simply to an expansion in the area put to maize. Figure 3.6 shows that in the latter part of the 1980s, between US$93 million and US$162 million might have been required annually to import between 619,000 and 1.1 million MT of coarse grain. Between 1986 and 1990, this would have involved an average annual 5-9% increase in the import bill, equivalent to adding between 1.6% and 2.8% to the nation's total external debt. This was equivalent to an increase of 13% to 25% of receipts of Official Development Assistance for 1988 (World Bank 1990a).

In humanitarian terms, the improvement in maize production has had an important effect on the 90% of Kenyans for whom maize is a staple food; the increase in maize production represents an improvement of between 27% and 58% of the daily calorie intake (1102 cal/day) (World Bank 1990a). Furthermore, without the improvements in agricultural GDP (4.4% to 8%) attributed to maize technologies, the agricultural sector would not have been able to keep up with the almost 4% annual population growth during the past two decades in Kenya.

Windows of Creativity

The initial two decades of maize research in Kenya provided a "window of creativity" that remains unequaled in size and duration by any other country in tropical Africa except Zimbabwe. Beginning in 1955, a team of young, enthusiastic scientists headed by Michael Harrison was given considerable latitude in the design and implementation of the research program. Prior to 1970 the national Maize Research Program was small and modestly funded, but enjoyed close working relationships with extension and the Kenya Seed Company. The highland areas of Kenya were ideally suited for maize production, and commercial producers in this zone provided direction and feedback for the research program as well as a ready outlet for innovations. Further, Harrison recognized the potential of Latin American germplasm and obtained these materials with the assistance of the Rockefeller Foundation. The breeding program, which included crossing local and Latin American cultivars, made good progress resulting in the releases of Kitale Synthetic II in 1961, and the first hybrids in 1964. These early successes made the program famous, nationally and abroad, enabling it to attract additional resources well into the 1970s.

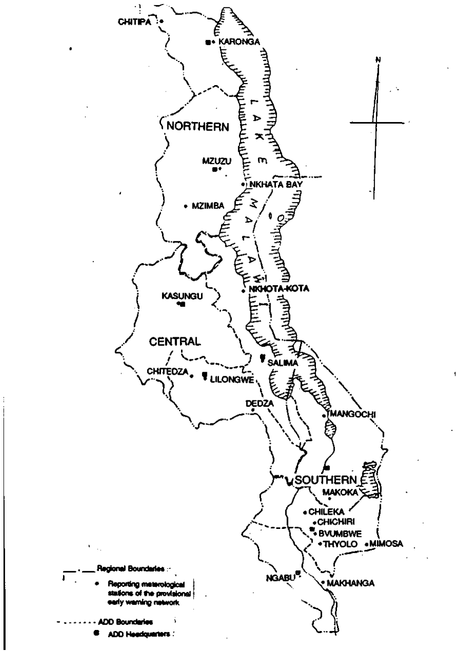
MALAWI[9]

As a case study, the history of maize research in Malawi is of policy interest for two principal reasons. First, although various factors suggest that the agroeconomic setting is favorable for intensification involving the use of improved varieties, farmer adoption rates have risen very slowly. Understanding adoption patterns in Malawi has implications for other maize-producing and maize-consuming zones.

Second, although the significance of flint maize preferences in household decision-making has long been recognized by the breeding program, a perceptible tension existed between the recognition of grain quality as a trait and the importance of yield criteria. For farmers who grow improved

9. This section is a summary of the MARIA case study for Malawi prepared by Melinda Smale.

Figure 3.7. Map of Malawi



varieties as a cash crop, processing and storage efficiency is of no significance, and yield at harvest is critical. Maize-deficit farmers who want to consume their maize are concerned about yield from the mortar. Spurred by donor involvement, flintiness and yield criteria have also been related to the issue of whether hybrids or OPVs should be emphasized.

Overview of Factors

Farming Systems and Consumption Patterns

Maize replaced millets and sorghum as the dominant foodgrain crop in Malawi only 60 to 70 years ago, but over three-quarters of the nation's cultivated area is now sown to maize each cropping season. Per capita, the quantity of maize Malawians consume as a starchy staple is perhaps the greatest in the world. In Malawi, "maize is life (chimanga ndi moyo)," and the ideal of producing sufficient maize for the maize porridge (nsima) needs of the household "informs everyone's actions and rationales for their actions before, during, and after the maize harvest."[10] Each "hungry season," when their maize stocks have been depleted, many farm households face undernutrition as maize prices rise prohibitively and supplies at local market outlets fluctuate. Food preferences and the risks associated with relying on product markets imply that in Malawi, farm household decision-making is motivated by the objective of producing enough maize to satisfy annual subsistence needs.

In the short term, land-saving technological change can only be achieved in Malawi through adoption of seed- fertilizer technology. Soil fertility maintenance using traditional methods such as fallowing and rotation has become increasingly difficult as farmers expand their maize area and monocrop in an attempt to secure family grain requirements in the face of chronically low maize yields. Releasing land for the cultivation of other food crops that are essential to improving nutritional standards and for production of export crops that earn valuable foreign exchange cannot be accomplished without improving maize yields.

Malawi has a labor-land ratio that is high by African standards (Binswanger and Pingali 1987) and agroclimatic conditions that are favorable for a seed- fertilizer transformation. Malawi's maize research program has released hybrids, synthetics, and composites for over 30 years, but until the 1980s, no more than about 10% of aggregate maize area has ever been sown to hybrids or first-year, open-pollinated varieties. Aggregate area in hybrids has remained fairly low because, even when farmers have adopted hybrid maize, they continue to devote a large proportion of household maize area to local varieties.

Certain consumption preferences of Malawian farmers, among other features of input supply and distribution, have been frequently cited as factors limiting the popularity of hybrid varieties. Malawians reveal a distinct consumption preference for the flinty varieties loosely

10. From villagers' statements, cited in Peters (1988).

categorized as “local,” or “maize of the ancestors (chimanga cha makolo).” These varieties are more efficiently processed into the fine white flour (ufa woyera) used to prepare the preferred type of porridge, and their hard grain is more resistant to weevil attack in storage than most of the denty, white hybrids that have been introduced in the past.

For this reason hybrid maize was, until recently, promoted as a cash crop, although some substitution of hybrid maize for local varieties in consumption is increasingly perceptible and is unavoidable for the food-deficit households who represent the majority in Malawi. In recognition of the importance of consumer preferences in smallholder adoption decisions, the Department of Agricultural Research (DAR) has periodically released semiflint OPVs. For the 1991-92 season, DAR also released two new semiflint hybrids, and promotional efforts are emphasizing improved processing and storability traits. Evidence suggests that the new semiflint hybrids perform well relative to both denty hybrids and local maize in terms of yield, processing, and storage characteristics (Smale et al. 1993; Jones and Heisey 1993).

Research

Malawi’s maize program, as compared to other conventional breeding programs in the region and elsewhere, did incorporate socioeconomic considerations into breeding objectives. Since its inception in the 1960s, the program has attempted to address the consumption preferences of small farmers, which are related to processing and storage characteristics of the flinty varieties, by breeding semiflint hybrids or semiflint OPVs. Each of Malawi’s major breeders in one way or another expressed concern for “yield from the mortar.”

The flint maize preferences of farmers did, nevertheless, contribute to complexity in breeding objectives in the early years of the program. At that time, the major constraint to breeding popular flint hybrid varieties was limited availability of local and exotic flint germplasm that was also high-yielding, short in stature, and early-maturing. Exotic flint germplasm was difficult to locate because the focus of most maize breeding efforts in other parts of the world had been denty varieties. Further, hybrids and synthetics were initially diffused primarily in the Lilongwe area. The greatest demand for hybrid seed was among commercial farmers whose foremost concerns were yield at harvest and production for sale. To meet the perceived demands of two groups of clients—commercial farmers and subsistence farmers—the program pursued the dualistic (and expedient) strategy of importing the high-yielding denty SR52 from Zimbabwe for cash crop production and developing flinty OPVs for smallholders. No active hybrid breeding occurred during the early 1970s.

The need to replace hybrid seed imports because of high costs led the maize research program to develop denty indigenous hybrids in the late 1970s. Breeding denty (rather than flinty) hybrids was the first step in indigenous varietal diversification and seed adaptation. Although importation and development of denty hybrids and their promotion as a cash crop effectively reduced the ceiling adoption rate by focussing on more well- endowed producers, the breeding program always worked with OPV alternatives designed to meet the maize subsistence needs of smallholders.

Two problems affected the progress of the OPV program: (1) discontinuity in breeders, and (2) a limited range of high-yielding, mid-altitude material suitable for developing Malawian lines. An example of the first problem is the deterioration of the synthetic lines bred by Ellis and their subsequent rejection by Bolton (Ellis 1959; Bolton 1974). An example of the second constraint is that, although CIMMYT breeders sent mid- altitude (at the time, “subtropical”) materials to Malawi in the 1970s and 1980s, their more attractive materials had not been developed until the mid-altitude station was established in Harare in 1985.

For OPVs to have been successful (in Malawi they have been moderately popular over brief periods in selected localities), they needed yield, disease-resistance, drought-resistance or early maturity, in addition to flintiness. The history of OPV successes shows that both OPVs as well as hybrids need to be "spectacular." In any case, OPV development is of continued importance in breeding lines for kernel texture and other desirable characteristics to use in the hybrid program, and in maintaining a varietal portfolio.

For either hybrids or OPVs to have been adopted at a steadier and faster rate would have required more of a commitment to seed production and distribution. Although it may be true that the involvement of a private seed company can provide a key impetus at certain stages of the breeding process, in most success stories the role of private companies in seed distribution has been even greater than their role in breeding. On the other hand, private seed companies are not usually as interested in OPVs. To guarantee that OPVs are given a chance with farmers, a conscious public sector effort is needed to distribute the seed widely and to educate farmers about the relative advantages and disadvantages associated with OPVs and hybrids.

Even the discontinuities in funding, staffing, and breeding objectives that were related to the turnover of expatriate breeders and the ebb and flow of financial support would not have jeopardized the program if there had been more senior Malawian breeders before the mid-1970s. Since then, although the three Malawian senior breeders have taken over decision- making responsibility, overseas training has caused some disruptions. The program will soon have three PhD- trained breeders with lengthy experience—but there is no "younger generation" of breeders in line to follow them. The sheer number, and not the quality of the personnel has been a problem. At this critical juncture in the breeding program, when the impact of recent varietal releases is becoming apparent, the need for a new generation of breeders to sustain varietal development cannot be overstated. The experience of the maize program has shown that the next generation of breeders is usually best drawn from promotions within the system, from technical to professional officer. Further, although the need for socioeconomic contributions to the maize program has been recognized since the early 1980s, the capacity for socioeconomic research has not been successfully institutionalized.

In addition to flintiness, other important traits affecting adoption are plant stature and length of the growing season. Other socioeconomic factors affecting adoption rates cannot be resolved through breeding. Examples are cited below.

Extension and Availability of Inputs

At various points in time, seed quality, multiplication, and distribution problems have interacted with other factors to inhibit farmer adoption of varietal releases. The rapid increase in sales over the past few seasons, since the National Seed Company of Malawi has assumed the role of supplier and distributor, suggests a latent excess demand for hybrid seed, so that in some years, seed supply may have actually been the limiting factor. Breeding and seed production under rainfed conditions affect the speed of varietal releases and seed supply. The costs of seed production also vary by hybrid type, affecting the varietal composition of supply. Further, because little was known about effective farmer demand, the varietal allocation of the fixed seed supply among agroeconomic zones has not always suited farmer preferences.

The Government of Malawi has promoted hybrid seed as part of a seed-fertilizer package that is extended through formal credit clubs with subsidized credit and stringent repayment requirements. In the past, the packages that were distributed to club members were of a fixed size and composition. Credit club members sowed the seed variety that was provided in the package and applied the type of fertilizer they received, on one- acre (0.4-hectare) plots. This diffusion method created a lumpiness in land allocation and curtailed farmers' experimentation and their ability to adapt the technology to their own conditions. Irregular marketing conditions have also impeded the purchase of both seed and fertilizer by non-credit club members. In rural areas, fertilizer and seed were initially sold at official Agricultural Development and Marketing Corporation (ADMARC) outlets. These markets were not evenly dispersed in all village areas, nor did they always stock inputs.

Perhaps as a result of early farmer responses to denty varietal releases, hybrids have been generally promoted as a cash crop. Focussing on the profitability of hybrid maize, combined with limiting its diffusion to credit clubs and emphasizing the importance of following rigid recommendations, may have limited the receptivity of large subsets of farmers, even those capable of self-financing. Extension messages with single themes were undoubtedly useful in the early introductions, but over time may have discouraged farmer experimentation that might have resulted in adoption and greater farmer benefits. For example, the emphasis on pure stand cultivation for hybrids is now relaxing as field workers observe that farmers in some zones have reasons for intercropping maize, whether it is a hybrid or a local variety. Smallholders who both consume and market crops have diverse objectives, and producing hybrid maize under conditions that may not be agronomically optimal may nevertheless make good economic sense.

On the other hand, continual exposure to other farmers who grow hybrid maize and recent radio messages that exhort farmers to grow hybrids has probably contributed to the upsurge in adoption, particularly in the southern region. Analysis of the CIMMYT/MOA data confirms that farmer experience with hybrid varieties increases the probability of sowing hybrids in successive years. Once a "critical mass" of hybrid maize growers accumulates in a given locality, the general level of knowledge about the varieties also increases. Those with limited levels of working capital are more able to experiment "passively" (by observation) than "actively" (by paying the costs of gaining information from their own fields). Farmers who observe success and who have the resources can then adopt at faster rates and there is an increase in the slope of the aggregate diffusion curve, as is now evident in the figures from the southern region.

Markets and Prices

Official output prices are announced seasonally, and are uniform for all varieties during the harvest season. Although few price series exist, with market liberalization there is increasing evidence of price differentials between hybrid and local varieties and intraseason price variation on local markets. The difference in the way farm households value local and denty hybrid maize may appear in price differentials in local markets but is suppressed in the official price. Because of consumer preferences for local maize and the credit repayment system, a higher proportion of hybrid maize circulates in official markets. Local markets in many rural areas are also likely to be thin, especially in certain seasons. When the official prices capture little economic information, and private markets have only begun to operate, either observing true valuations for maize or studying farmers' responses to these valuations is difficult.

Farm-Level Impacts

Household Characteristics of Adopters and Nonadopters

As in other HYV adoption settings, farmers who adopt hybrid maize in Malawi are more likely to be male, members of credit clubs, and to operate larger areas (Table 3.4). Wealth influences opportunities for adoption, and credit

Table 3.4. Relationship of Farm Household Characteristics and Hybrid Maize Adoption

Household adoption characteristic	Percent of subgroup sowing hybrid maize	Mean percent of maize area sown in hybrids by adopters
Sex of household head*		
Female	17	39
Male	38	43
Credit club membership*		
Yes	76	44
No	17	40
Farm size class*		
less than 0.7 ha	13	44
0.7 to 1.5 ha	36	44
more than 1.5 ha	56	37
Local maize subsistence ratio†		
less than 1	33	30
1 or above	40	48**

* Statistically significant differences between subgroups (5%), chi-square test.
** Statistically significant differences between subgroups (5%), t-test.
† Actual local maize output / minimum states maize subsistence requirements.

Source: Maize Variety and Technology Adoption Survey, CIMMYT/MOA, 1989-90. N=420 farmers in Blantyre, Mzuzu, and Kasungu Agricultural Development Divisions.

relaxes expenditure constraints, facilitating adoption—if only for a season. The larger the land area, the more likely is the household to qualify for credit or to have alternative crops that generate cash income. Female heads of households who are divorced or widowed tend to be less wealthy and are less likely to be club members, and therefore have fewer opportunities to adopt. The primary diffusion mechanism for the seed-fertilizer technology package has been the formal credit system, which has favored joint households and larger farms. This interrelated cluster of factors, which often translates loosely into "control over resources," is associated with the probability of adoption but disguises diversity in the adopter population.

For example, survey data also demonstrate that female- headed households, non-credit club members, and smaller farmers do adopt innovations. Certain cultural traditions imply de jure female-headed households are more prevalent in the South where farm sizes are also smaller. Women in that region generally have matrilineal rights to land, but small farm size has constrained their choices. Given consumption preferences and, until recently, recommendations for growing hybrids in pure stands where intercropping is more prevalent, many women probably did not feel they had "enough land" to grow hybrid maize (Hirschmann and Vaughan 1983). Maize is clearly a women's crop to the extent that it is a food crop, but in any region all household members work in the maize fields. Hybrid maize purchased on credit may be more of a "men's crop" in the North, for example, where cultural traditions are also patrilineal. In no sense, however, is the concept of "women's crops" and "men's crops," as it has been used elsewhere, particularly useful in the analysis of hybrid maize adoption in Malawi. Producing sufficient maize is the common objective of every individual in any Malawian household.

Anecdotal evidence from the 1989/90 CIMMYT/MOA survey illustrates the implications of different farm sizes among adopters. Farm size is related to farming systems and farmer objectives, and not just to credit eligibility. One of the subsets of hybrid maize growers was found in Thyolo. These farmers grew short-season hybrid maize on tiny plots to consume or sell green in Blantyre city, for supplementary food or cash during the hungry season. They also worked off the farm to meet their local maize consumption needs and to buy their inputs. In contrast, some of the hybrid maize growers in the Kasungu and Mzuzu areas sold over 2 MT of hybrid maize in the previous year, producing 3 to 4 MT/ha yields by applying high analysis fertilizer and using animal draft power for land preparation. These farmers also had enough land to produce large outputs of local maize, satisfying their consumption requirements at the same time that they earned profits from their hybrid maize. Both sets of farmers may have grown hybrid maize for different economic reasons.

Non-credit club members also adopt innovations. In 1989/90, hybrid maize adopters in the Blantyre survey zone were more likely to be self-financed and to have first learned about improved seed from other farmers rather than extension agents. In the past, the fact that credit packages have consisted of seed and fertilizer in fixed quantities also means that land allocated to hybrid maize by credit users has exhibited a lumpiness around 0.4 ha (one-acre) intervals. For hybrid maize growers who are not credit club members, there is greater variation in hybrid maize hectarage.

The CIMMYT/MOA data also confirm that, in Malawi, adoption patterns, sex of household head, farm size, and credit club membership vary by zone. In aggregated figures, differences in these variables as they relate to adoption are, to a large extent, differences associated with agroeconomic zone. Within zones, differences are less evident. For example, within the Blantyre survey zone, female-headed households were no less likely to adopt than male-headed households, while in Mzuzu zone, they were. Similarly, although pronounced among the Kasungu and Mzuzu survey farmers, differences in the likelihood of adoption between farm size classes were not significant among the Blantyre survey farmers.

Finally, sex of household head, credit club membership, and farm size may affect probabilities of adoption, but are less likely to influence the proportion of maize area that adopters plant in hybrids. In the CIMMYT/MOA data, even when farmers planted hybrids, they continued to devote the major portion of their maize area to local maize. Both adopters and nonadopters preferred to consume local maize, although some substituted their own or purchased hybrid maize during maize-deficit seasons. The household characteristic that is more likely to affect land allocation to varieties by adopters is the ratio of local maize subsistence requirements to the local maize output their land can produce.

Management Practices of Adopters and Nonadopters

Adopters in the survey zones both obtained and believed they could obtain higher yields from their local maize. Partial explanation for this finding is provided by evidence that adopters were more likely to apply fertilizer to their local maize and, when they used it, they applied a higher rate of N/ha. Often farmers reallocate some of the fertilizer received on credit as part of a hybrid maize or tobacco package to their local maize, but in recent years fertilizer has been available on credit specifically for local maize, and some club members purchase additional fertilizer with cash. Fertilizer application, however, does not explain all of the difference between actual and observed local maize yields for adopters and nonadopters. Unfertilized local maize yields differ between the

Table 3.5. Resource Availability and Allocation Indicators, Hybrid Maize Adopters and Nonadopters

Characteristic	Subgroup Adopters	Nonadopters
Mean farm size (ha)	1.68*	1.07*
Maize area	1.42*	0.92*
Area in other crops	.26*	0.14*
Mean hectares / adult (gt 12 yrs)	.60*	.41*
Mean percent of cultivatred area in maize	86*	90*
Hectares / adult class	**Percent area in maize**	
Less than 0.25	95	95
.25 to .39	86	92
.40 to .59	85	86
.60 or above	85	83
Mean annual earnings from off-farm labor (MK)	136	143

* Statistically significant differences between subgroups (5%), t-test.

Source: Maize Variety and Technology Adoption Survey, CIMMYT/MOA, 1989-90. N=420 farmers in Blantyre, Mzuzu, and Kasungu Agricultural Development Divisions.

groups, suggesting that other management or human capital variables may play a role.

Between varieties, as expected, farmers devote more labor to land preparation for hybrid maize because they more frequently plant it on fallowed land. Although hybrid maize tends to be planted later, more time is required in planting because of greater planting densities and, according to many survey farmers, because "greater care is needed to follow recommendations." In addition, more hybrid area than local maize area is weeded twice.

Resource Availability and Allocation, Adopters and Nonadopters

Adopters tend to have both larger total areas and larger areas in other crops (Table 3.5). Although, on the average, maize as a percent of household cultivated area differs statistically between adopters and nonadopters (because of small standard errors), the difference is hardly meaningful. Even after farmers have adopted hybrid maize, they continue to sow a large portion of total cultivated area in maize both because of the dominance in the diet and the economics of the cropping system.

In general, hybrid maize area substitutes for local maize area rather than releasing land for cultivation of other crops. Per hectare net returns are probably higher in most years for hybrid maize than for many of the alternative crops smallholders can grow (groundnuts, beans, cassava, sweet potato). In Mzimba District of the Mzuzu zone, hybrid maize is a cash crop. Among the survey zones, perhaps the greatest reallocation of farmers' area is found among Kasungu farmers who have the opportunity to grow highly remunerative tobacco. Kasungu farmers were also more willing to consume their own hybrid maize.

The farms of adopters also have greater capacity (hectares per adult over 12 years of age) to support the starchy staple needs of the family. The very slow decrease in the percent of farm area sown to maize as the labor/land ratio rises underscores the importance in farm household objectives of attempting to satisfy maize subsistence requirements. Controlling for farm size and labor capacity does not diminish the most salient feature of farming systems in Malawi.

When cultivated following recommendations and even when adapted to most farmers' conditions, farmers use more labor per hectare for hybrid maize than for local maize varieties as they are typically grown. On the average, however, adopters do not appear to reallocate labor from off-farm to farm activities but within farm activities.

Household Income and Consumption, Adopters and Nonadopters

The mean value of total crop output for adopting households is 2.5 times the value for nonadopters, primarily because of increased maize output, but also as a result of their other crop production. The importance of maize as a percent of the total crop value is the same for both groups, while maize as a proportion of total annual income flows increases in significance for adopters.

Average maize output per adult triples with hybrid maize adoption. Mean minimum annual maize subsistence requirements are higher for the adopting households because they tend to be larger; but, because their farm sizes are also greater, the amount of maize per hectare they need to produce to meet their requirements is lower. Consequently, adopting households are better off both with respect to absolute maize output and maize output relative to requirements.

If other factors were held constant, the boost in maize output could imply improved caloric intake and, through maize sales, a diversified diet (more oils and protein) for adopting households. Other factors are likely to dilute, but not offset, the apparent consumption and nutritional gains. First, because many of the adopters are club members, some of their hybrid maize output is used to repay loans. But even when hybrid maize is not sold to repay loans, denty hybrids are usually sold to meet cash needs because of their poor storability and processing characteristics. In this way, denty hybrids may have had less effect on nutrition than the new semiflint hybrids. To the extent that local maize is more frequently intercropped than hybrid maize, growing hybrid maize could have a slight negative effect on nutrition. Since most adopters also grow local maize and, in zones where intercropping is frequent hybrid maize is increasingly intercropped, the last effect is likely to be negligible.

A positive effect of hybrid maize adoption on nutrition is that farm households who grow earlier maturing hybrids are able to consume more green maize in the hungry season and harvest earlier. If it is true that mgaiwa (wholemeal flour) is more nutritious than ufa woyera (refined white or "pure" flour), adopting households who consume their own hybrid maize as wholegrain flour may also receive some nutritional benefit.

Potentially, the food security position of hybrid maize growers could be less precarious, but the food security impact of hybrids is probably more evident on an aggregate than on a household level. Without the hybrid maize output marketed by adopters, maize-deficit households would probably have to pay higher maize prices in the hungry season—if they could procure maize at all. In part, the marketing system for hybrid maize has operated to redistribute the less preferred varieties, at a cheaper consumer price, from production surplus to deficit areas. When it is valued in terms of national food security, the shadow price of hybrid maize output is greater than its nominal value.

Yield and Economic Risks of Hybrid Maize Adoption

A comparison of either observed or expected cumulative yield distributions for fertilized

Table 3.6. Labor Returns and Total Factor Productivity, Hybrids and Local Maize

Characteristic	Maize technology: Fertilized hybrid	Fertilized local	Unfertilized local
Yield (kgs/ha)	2,774	1,264	745
Price (MK/kg)	0.29	0.29	0.29
transport and harvesting costs	0.04	0.04	0.04
Gross returns (MK/ha)	694.50	316.00	186.25
Seed costs[1] (MK/ha)	37.00	6.50	186.25
Fertilizer[2]	196.35	72.10	--
Credit charges	28.00	8.65	--
Variable costs (MK/ha)	261.35	87.25	--
Gross margins (MK/ha)	432.15	228.75	179.75
Gross margins / person-hour[3] (MK/hr)	1.16	0.66	0.59
Total factor productivity[4]	1.49	1.10	0.95

1. 25 kgs/ha.
2. For hybrid maize, 170 kg/ha urea and 85 kg/ha DAP; for local maize, 75 kg/ha urea and 20 kg/ha DAP.
3. 6-hour days, 62 person-days for hybrid maize, 58 person-days for fertilized lcoal maize, and 51 person-days for unfertilized local maize. Modest rural wage = MK 1.3 (CIMMYT / MOA).
4. Rental rate for land = MK 123.50 (Jere 1990).

Source: Maize Variety and Technology Adoption Survey, CIMMYT/MOA, 1989-90. N = 420 farmers in Blantyre, Mzuzu, and Kasungu Agricultural Development Divisions.

hybrid maize, fertilized local maize, and unfertilized local maize demonstrates that the fertilized hybrids grown in Malawi are less risky with respect to yield than either fertilized or unfertilized local varieties. On the other hand, relative riskiness of net returns (one aspect of economic risk) depends on the pricing relationships assumed. If local maize is given a value premium expressing superior processing and storage efficiency and households are assumed to produce local maize only for home consumption, fertilized local maize appears less risky than fertilized hybrid maize. When the conventional assumptions used to compare profitability are employed, the results are inconclusive and depend on the nature of individual farmer's attitudes toward risk (Smale et al. 1992).

In other words, for all farmers, yield prospects are less risky with hybrids. For some farmers, however, hybrid maize cultivation poses more of an economic risk than local maize production. The fact that no single technology dominates with respect to riskiness of returns suggests that farmers may be able to reduce total economic risk by sowing a portfolio of varieties.

The cumulative distributions also show that the total probability of negative returns, or "downside risk" is always greater with fertilized hybrid maize relative to fertilized or unfertilized local maize. When farmers operate with limited resources, producing a small surplus in one year and a deficit in the next, the risk of low or negative economic returns may be of primary importance in their decision-making.

Returns to Labor and Total Factor Productivity, Hybrid and Local Maize

Returns to labor in maize production for local maize (fertilized and unfertilized) and hybrid maize (fertilized) have been constructed using experimental data for labor hours and CIMMYT/MOA survey data on returns, expenditures, and wages (Table 3.6). The figures are comparable to, but lower than, those calculated in representative budgets by Planning Division, Ministry of Agriculture. On the average, under farmer conditions in 1989/90, adoption of hybrid maize roughly doubled returns to labor in maize production.

Preliminary estimates of total factor productivity (the value of output divided by the total value of inputs) were also calculated for the three maize technologies. Estimated total factor productivity for unfertilized local maize is 0.95; for fertilized local maize 1.10; and for fertilized hybrid maize, 1.49. The figures suggest that unfertilized local maize, still the dominant technology, is relatively unproductive in Malawi's land-scarce conditions. Fertilization (at average rates for the sample) improves estimated total factor productivity by approximately 15%. Adoption of hybrid varieties plus fertilization increases it by over 50%. The predominance of maize in the cropping system, even when total factor productivities are generally so low, may be explained by the lack of alternative crops, the conventional pricing assumptions employed, or both.

For example, less conventional assumptions might reflect such considerations as (1) the majority of farm households produce less than their maize subsistence requirements; (2) yield losses in processing can be as high as 25% for denty hybrids; (3) losses for untreated denty hybrids are also very high; and (4) costs of procuring fertilizers are much higher for farmers who are not club members. With these assumptions, the comparison of technologies favors fertilized local maize. The same calculations can be produced with various sets of assumptions (that are meant to characterize various farmer subsets) and generate contradictory sets of figures.

National-Level Impacts

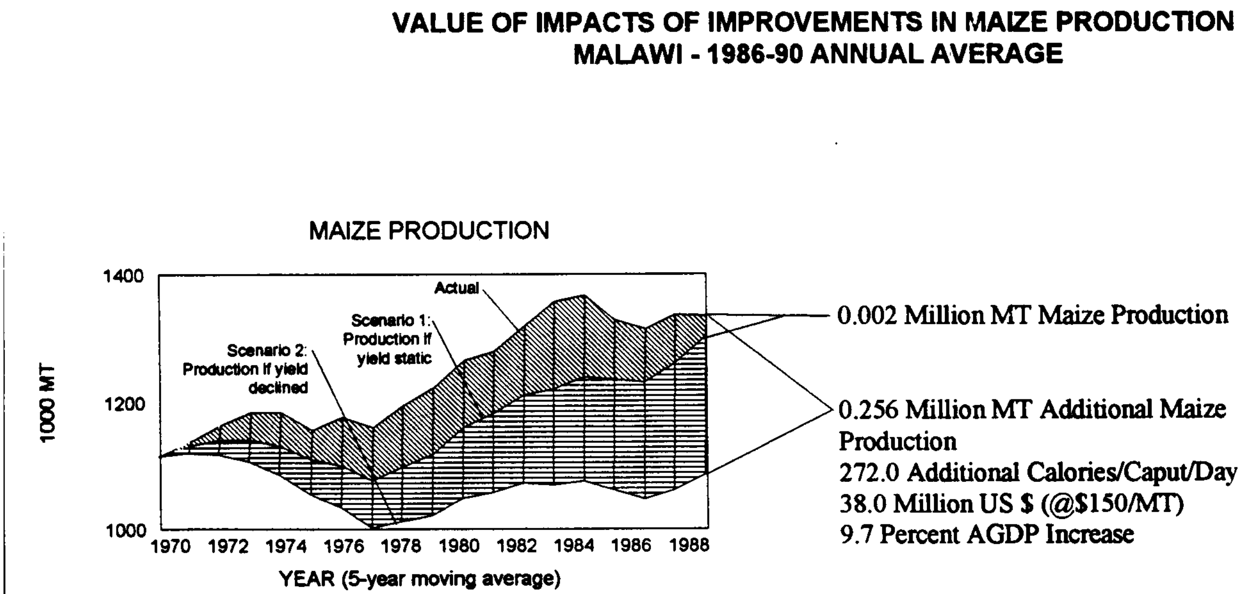
The assumptions used to construct the scenarios for Malawi differ slightly from those used for other MARIA case studies because of the role of maize in the agricultural economy. For the "actual" case, exponential trends are fitted to maize yield, area, production, and consumption (availability) data to smooth fluctuations resulting from climatic conditions. Net imports is the estimated residual of production less consumption and change in stocks.

Figure 3.8 shows the actual, static, and declining maize production scenarios calculated with the method described in Annex D, using USDA/ERS data for Malawi. Based on five-year moving averages, the estimated gap between the actual and declining scenarios reaches about 250,000 MT in 1988—20% of total maize output in that year. In other words, with declining soil fertility or disease, and without offsetting varietal innovations, the national maize crop would have been significantly reduced.

In the Malawi case study, the same data was used with a different set of assumptions from those used in Figure 3.8. In order to emphasize the unique role of maize in Malawi's agricultural economy, consumption figures were used to calculate net maize import and GDP series from the production data.

In Scenario I, or "static yield," yields are held constant at the 1961-65 average, maize area changes according to the "actual" trend, and per capita consumption is held constant at the 1961-65 average. Of particular importance is the fact that, because per capita maize avail-

Figure 3.8. Malawi Maize Production, with and without Technological Change



ability exhibits a declining trend over time, the 1961-65 average is slightly higher (230 kgs/person) than the average for the 1986-1990 period (190 kgs/person). Net imports are then calculated as in the "actual" case, as the residual from estimated figures. Agricultural GDP and GDP series are tabulated by adding the real value of maize production estimated under Scenario I to the "actual" agricultural GDP and GDP series from all nonmaize production.

Scenario I depicts the production, net imports, and GDP situation when farmers manage to use enough fertilizer to maintain maize yields despite declining soil fertility from maize monocropping over an extended time period. No new varieties are released. The government has a major policy goal of sustaining per capita maize availability at 230 kgs/person, which is considered the minimum tolerable level of consumption. Production shortfalls relative to consumption requirements result in increased net imports. Maize area expands to further dampen the effects of declining soil fertility and temporarily buoy national production levels, with deleterious effects over the longer term because more marginal lands are opened and the economy becomes more dependent on a single crop. Under Scenario II, production reaches an asymptote as the proportion of total cultivable area sown to maize reaches 1 or all farmers apply fertilizer at their economic optimum, whichever occurs first.

In the Malawi case, Scenario II expresses "declining yield." Maize yields decrease at 1% per year from the 1961-65 average, area expands at the "actual" rate, and per capita consumption is held at the level consistent with food policy goals. Net imports and GDP figures are calculated by the same method described in Scenario I, with Scenario II production figures. In Scenario II, no fertilizer is used and no varieties are released. Population pressure and consumption preferences slowly deplete the land resource base with no offsetting technological change.

For each scenario, the production, net maize imports, and agricultural GDP implications were tabulated. Actual yield trends, combined with expansion of hectares sown to maize, have caused national maize production to roughly double since 1961. That increase is approximately halved in the "static yield" scenario, with no maize research and limited use of fertilizer. In the “yield decline” scenario, maize production is nearly unchanged in 1990 from the 1961 level, and is kept at that level only through continual expansion of maize area. If maize area were held constant to express a policy goal of at least some diversification of crop output (recall that 1961 maize already occupied an estimated 66 to 75% of cultivated area), maize production would decrease in Scenario II.

If Malawi were autarkic, the results of either Scenario I or II on food security would be dramatic. Maize area would expand quickly to maximum cultivable area and there would be no means by which to sustain the population. Prices would rise prohibitively, and the government would need increasing funds to subsidize consumer prices. To meet minimum consumption needs, even if Malawi trades, the effect of either static or declining yields is to increase net imports six- and tenfold in recent years. If maize area expanded more rapidly to offset static or declining yields, the area devoted to alternative export crops would diminish, and Malawi’s agricultural-based economy would gradually become unable to finance the volume of imports. Even if maize area expanded at the “actual” rate, agricultural GDP would be cut by an average of 9% per annum in Scenario II. Total GDP would be reduced by up to almost 4% each year. There would be no recourse for the government but greater indebtedness, with little means for repayment.

A more complete macroeconomic model would be necessary to generate reliable quantitative estimates of research impact for the various scenarios, but the essential point remains clear: without maize research and at least gradual technological change, Malawi’s food security and macroeconomic position would rapidly deteriorate. In an agricultural-based economy where both national and agricultural production and individual producer livelihood is based on maize, maize research is critical. Thus, the value of maize research cannot be overstated. The relevant policy issue is how to increase maize research impact by speeding the technology adoption process.

Windows of Creativity

The recent release of two adapted, semiflint hybrids by Malawi’s national research team is an example of how the scientific creativity of several individuals has coincided with certain conditions to generate the potential for rapid technological change. The new hybrids are the first semiflints developed since the colonial period, and have the processing and storage traits valued by small farmers and yields that compare well to the denty hybrids previously grown as cash crops (Smale et al. 1993).[11] The speed of their release (only 3 years after the initiation of the semiflint hybrid program in 1987) can be attributed in part to the convergence of several factors, including (1) the idea of breeding a top-cross rather than a conventional hybrid; (2) the comfortable working relationship with CIMMYT’s regional breeders that enabled the Malawi team to identify appropriate parent material in Population 32; and, most importantly, (3) the years of development and maintenance of parent lines by technicians and breeders as they gradually accumulated germplasm and experience. The work of the three senior breeders—B.T. Zambezi, E.M. Sibale, and G. Nhlane—was publicly recognized for the first time when they received the MASTA (Malawi Award for Scientific and Technical Achievement) from the Government of Malawi for the new hybrids, MH17 and MH18. Additional donor support to the maize program may have facilitated the team’s progress by enabling its members to obtain advanced degrees and pursue their research with fewer operational constraints. However, without the dedication of the breeders to their work during more

11. A complete report on these developments can be found in “Farmers’ Evaluation of Newly Released Cultivars in Malawi: A Comparison of Local Maize, Denty, and Semi-Flint Hybrids” by Melinda Smale, Z.H.W. Kaunda, H.L. Makina, and M.M.M.K. Mkandawire, International Maize and Wheat Improvement Center (CIMMYT), Lilongwe and Harare, 1993.

difficult years, the breakthrough would not have occurred so rapidly. Concurrently, adoption rates for denty hybrids have been rising as weather conditions underscore the yield advantages of the shorter-season hybrids over farmers' varieties, and as the quantities of seed produced and marketed increase. The scientific breakthrough, together with farmers' growing receptivity to hybrids and gradual improvement in seed production and marketing, have created a situation that is ripe for major technological change in Malawi's farming communities.

NIGERIA[12]

Nigeria is Africa's most populous country and is growing at a rate of about 2.7% per year.[13] Aside from wheat, the country has been able to meet most of its own staple food needs.[14] The development and adoption of agricultural innovations, especially maize and cassava varieties, have played important roles in this process. Agriculture accounts for about 40% of GDP despite the importance of petroleum, industries, and services, and is the primary livelihood for the majority of Nigeria's population.

Throughout 30 years of independence, Nigeria has been subject to a succession of economic and political shocks that have had major consequences for the ability of agricultural institutions to operate effectively, as well as for the country's growth and development as a whole. Nigeria's natural wealth, especially its oil reserves, together with the size, diversity, energy, and talents of its population, have combined and clashed in fashions that have made political and economic progress fitful at best. The country has experienced civil war, several military coups, and frequent civil unrest stemming from ethnic, religious, political, and socioeconomic grievances. Population growth, petroleum, war, and perverse policies have combined to undermine traditional agricultural exports of oil seeds, cotton, and cocoa.

In spite of these problems, Nigeria moves forward. The federal government has been able to keep the country together, but the process for returning the country to civilian rule has been fitful. Although GDP registered a serious reversal during the early 1980s as a result of falling petroleum prices and revenues, Nigeria has experienced growth rates of approximately 5% since 1988. External debt, which was insignificant in the mid-1970s at the height of the oil boom, rose precipitously in the early 1980s, but has stabilized somewhat since then (Figure 3.9). By virtue of its size and economic power, the country will remain a major actor in West Africa and the SSA region as a whole.

The changes that have occurred in maize technology and production in the past two decades dramatically illustrate the dynamism and potential of Nigeria's agricultural sector. Although agricultural policies governing prices and input supplies have often given producers the wrong signals or, more frequently, restricted the supply of improved inputs, maize has made dramatic progress nonetheless; production has nearly doubled in the last 25 years.

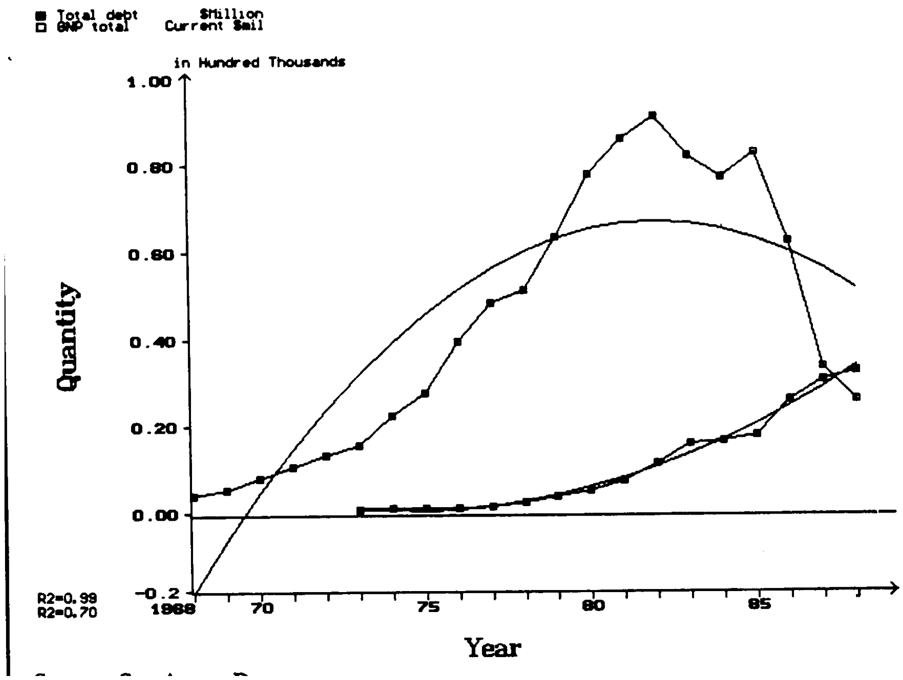
This section begins with an overview of the major factors that have influenced both the expansion of maize and the changes in Nigeria's agricultural sector, including the nature of the farming systems, research, extension, and agricultural policies. This is followed by assessments of the impacts of maize technology changes at the farm, district, and national levels. Specific attention is given to the experiences in the Northern Guinea Savannah where a major expansion in maize production has occurred and is associated with research and development activities collaboratively undertaken by national and international institutions.

12. This section is a summary of the MARIA case study for Nigeria prepared by Lucie Colvin Phillips and Elon Gilbert.

13. The November 1991 National Census provisional totals reported 88 million inhabitants. This result is significantly below previous estimates of well over 100 million by 1990.

14. Restrictions on food imports have undoubtedly played a major role, particularly since 1985.

Figure 3.9. Nigerian Macroeconomic Trends



Source: See Annex D.

Overview of Factors

Farming Systems

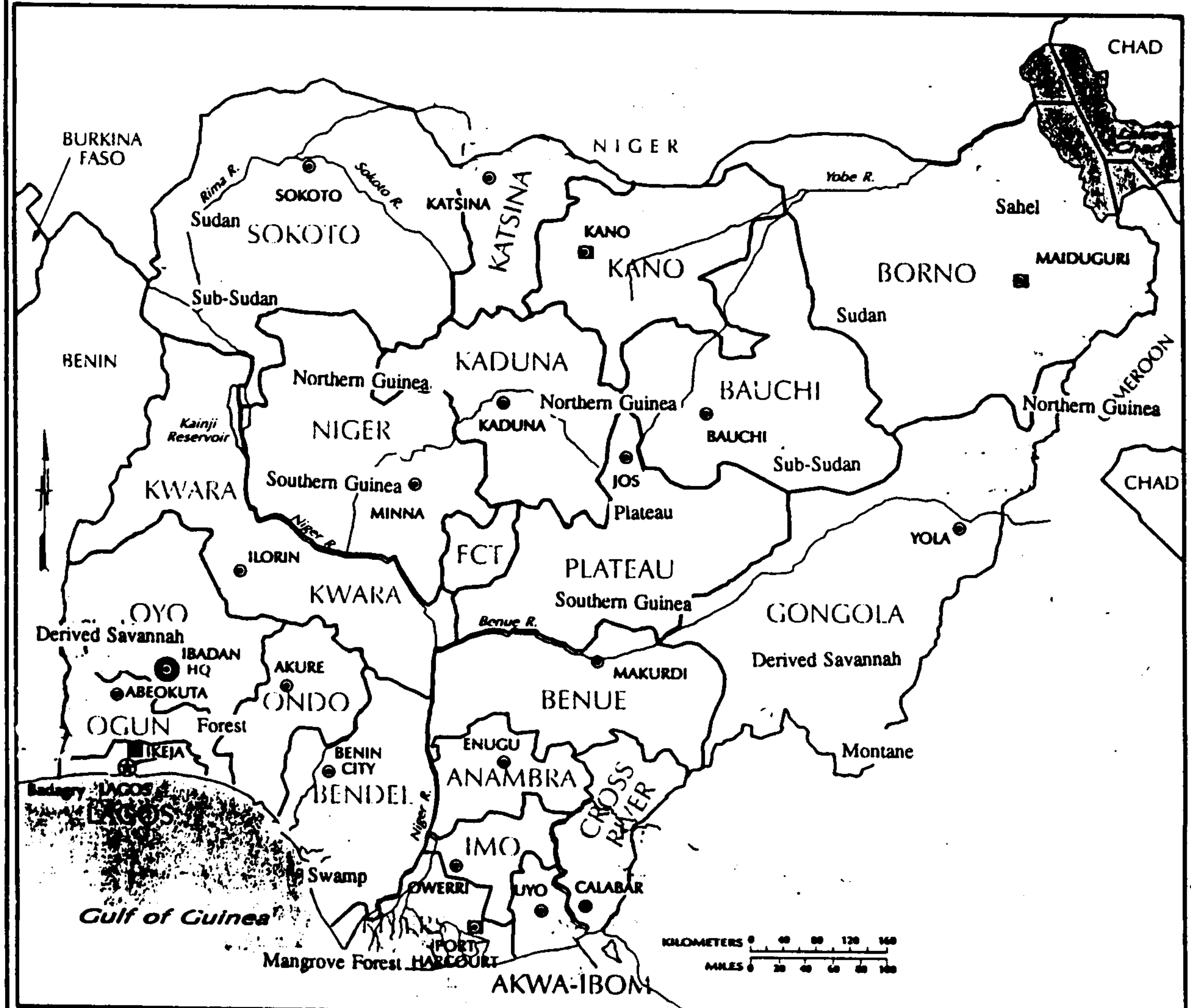
Nigeria's land area encompasses all the major agroecological zones of West Africa, from the Sahel to rain forest. Although maize is present in farming systems throughout the country, the discussion focuses on the Northern Guinea Savannah, which has experienced dramatic changes in the past three decades. In this zone, which encompasses major portions of the northern tier of states, 700-1000 mm of rain falls during a single, 3-month rainy season. The climate is well suited to coarse grain production (sorghum and millet as well as maize), which dominates the cropping patterns of the area.

The Hausa people comprise the overwhelming majority of farmers in the central and western portions of this zone, with greater ethnic diversity occurring as one moves east toward the Cameroon border. The farming systems described in this section are basically those of the Hausa of northern Kaduna and the southern portions of Katsina and Kano States.[15] Through the mid- 1970s sorghum and millet were the dominant staples on the upland fields with substantial hectarage devoted to the traditional export crops, groundnuts and cotton.

Hausa farmers distinguish between two types of upland fields according to fertility levels and management: (1) the cultivated fields that are manured annually and located closest to farmers' houses; and (2) fields cultivated from land in bush or grass fallow systems that are more distant (Norman et al. 1982). Most of

15. This section draws upon the studies carried out in the area by the Institute of Agricultural Research (IAR) during the 1970s as consolidated in Norman, Simmonds, and Hays (1982), and the studies by Polly Hill (1972 and 1982). The geographic focus of the latter is northern Kastina, but the farming systems and particularly the social system have strong similarities with the southern part of the state.

Figure 3.10. Map of Nigeria



these fields are intercropped (cereal/cereal or cereal/groundnut/ grain legume), a practice that reduces risk and improves returns to manual labor during the peak labor period.

Large areas around urban centers have been intensively cultivated without fallowing since the precolonial period (Mortimore 1967). Farmers have traditionally used manure and compound wastes to maintain fertility. Significant quantities of organic fertilizer were obtained from the urban areas through a long-standing trading system using donkeys.

The lowland fields known as fadama are subject to seasonal flooding or waterlogging, and rarely exceed more than 10% of cultivated area. Farmers use fadama for irrigated crops during the dry season, making year- round cultivation possible. They are favored for the production of higher-value, more labor-intensive crops, including sugarcane, onions, rice, tobacco, vegetables, and condiments.

Prior to the mid-1970s, maize was grown almost exclusively as a fadama crop on a very limited scale and largely consumed as green maize. Since then, maize has become a main component of upland farming systems, expanding in the face of major contractions in sorghum, groundnuts, and cotton. Improved varieties, as well as the natural suitability of the commodity for savannah- zone production, were major factors in this shift in cropping patterns.

Cattle, small ruminants, equines, and poultry constitute an important form of food and farm capital and provide draft power, transport, and manure in support of farming activities. Hausa farmers have used manure and household refuse to maintain soil productivity for many years, but as population grows and fallowed land becomes rarer, farmers must intensify inputs to maintain soil fertility. Use of inorganic fertilizers in Nigeria has increased steadily since the early 1970s, particularly in the Northern States, despite irregularities in supply. A portion of that expansion was fueled by subsidies, both direct and via overvalued exchange rates.

Hausa farmers have usufructuary rights over their land. Land fragmentation and conflicts between herders and farmers were problems in the sixties and seventies (Norman et al. 1982). Reductions in rainfall during the past 25 years, however, has made farming in northern zones less attractive and there are indications that the area under cultivation is declining.16 At the same time, forms of intensification are taking place in the better-endowed areas via reductions in fallowing and greater use of yield-enhancing inputs (seed, fertilizer, pesticides, and herbicides) (Smith et al. 1990). Mechanization, involving both animal traction and tractors, has expanded dramatically during the past three decades.

Some indicators of patterns of use of improved inputs and trends in landholdings suggest that larger, commercial operations have become increasingly important in land area and total production in recent years. There have always been important wealth differences among farmers in the region (Hill 1972), and agricultural policies and general economic conditions have widened the gap, expanding the importance of commercial farming. The expansion has increased the demand for effective input delivery systems, but has disturbing implications from an equity perspective. There is a growing tendency for small, low-resource farmers to hire themselves out to richer producers, even in preference to expanding their own production (Hill 1972).

Research

In terms of total resources, Nigeria has the largest agricultural research capacity of any SSA country. The country inherited the strongest research system in West Africa at the time of independence and has expanded it dramatically since then. The International Institute for Tropical Agriculture (ITTA) was established in Ibadan in the 1960s. The presence of IITA, whose current mandate includes regional West African responsibilities for maize, has further enhanced research capacity and the attention given to the problems of Nigeria's farming systems.

Significant progress was made during the 1960s and 1970s on a number of fronts, including maize. In the wake of budget constraints through the 1980s, however, the largely publicly funded national research system has been faced with declining real funds for operations and capital expenditures. The sheer size of the research establishment and its associated requirements for wages and salaries has consumed a major share of available funds and performance levels have declined.

Research attention to maize dates primarily from the 1960s when the USAID-supported Major Cereals Project operated in the country. Work was initially confined to the south where maize was already established as part of the farming systems. It was not until the 1970s that the commodity's potential in the savannah areas was recognized (Kassam et al. 1975). On-station trials at the Institute of Agricultural Research (IAR) found that improved maize varieties out-yielded local and improved sorghum and millets by 2 to 3 times. In addition,

16. The evaluations of the World Bank projects in Kano and Sokoto showed actual declines in total area under crops, as do national statistics for sorghum, millet, and groundnuts which are the dominant crops in the northern zones.

when trial results were compared from both north and south locations, it was found that savannah maize yields were consistently higher than forest or derived-savannah maize yields.

IITA, IAR, and the Institute for Agricultural Research and Training (IAR&T) in Ibadan have been responsible for most maize research in Nigeria. High-yielding, open-pollinated varieties (TZB and TZPB) have been available since 1973, and it is estimated that 90% of maize area is planted to these and other improved cultivars. These varieties combine higher yields with resistance to lowland rust and blight, which had previously plagued Nigerian maize, particularly in the forest zone. In the drier northern savannah, farmers find these varieties (notably TZB) drought resistant, whereas in the more humid south, farmers use TZPB and are able to produce two crops per year. TZMSR has been introduced by IAR&T/IITA into the midaltitudes and DMRLSR into southern areas which experience downy mildew (Weber, pers. comm.) An estimated 12% of the seed used by Nigerian farmers consists of varieties resistant to downy mildew and maize streak virus, available since 1986 in both open-pollinated and hybrid cultivars (Smith et al. 1990).

TZB was developed from the Nigerian Composites A and B created during the sixties. IITA found that TZB gave 50 to 100% superior yields compared with local varieties (Smith et al. 1990). Breeders selected for white grain that is even whiter than the sorghum used to prepare the staple food of the north, which has helped its adoption as a food crop. Although this variety is a high flour producer, it is difficult to pound into flour manually. Small grinding mills, however, are now widespread in both rural and urban areas throughout the country.

In the 1980s, the Nigerian government supported research at IITA to develop numerous inbred parent strains of hybrids, and these were introduced in 1985 by Agseed, the country's first private seed company. In 1986, its peak year, Agseed sold 1000 MT of seed. Since then sales have levelled off at about 500 MT/yr. Despite the fact that Agseed began operating at a loss and many large private farms have failed, four more private seed companies are starting up, which suggests that future prospects for the industry are positive.

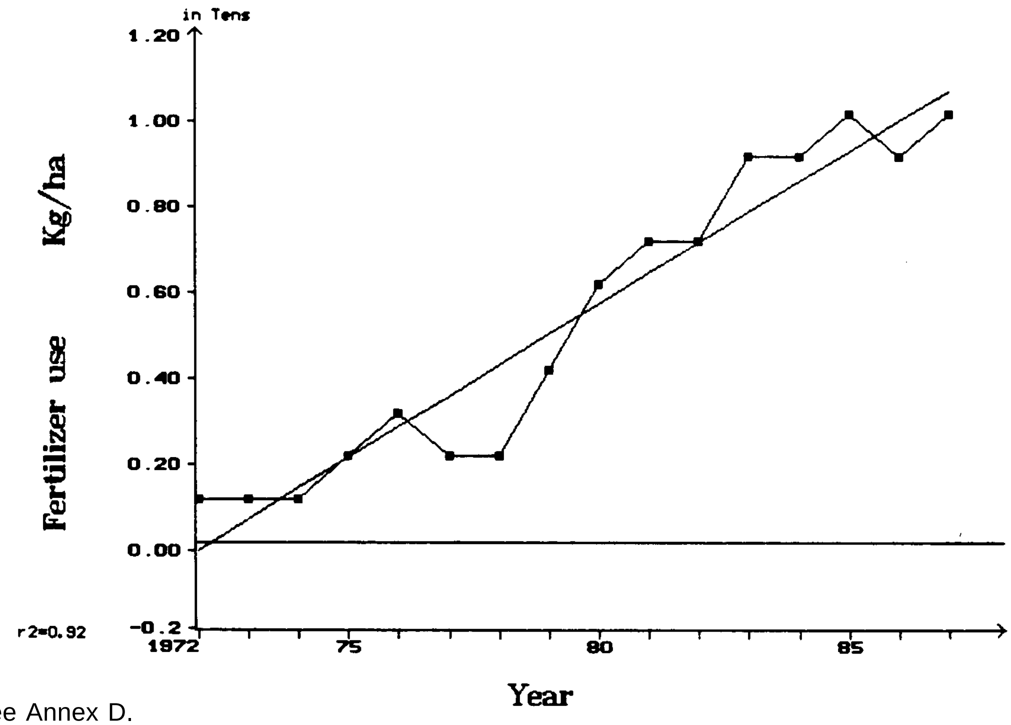
The Northern Guinea Savannah also benefitted from attention by socioeconomic researchers associated with the Rural Economic Research Unit (RERU) of IAR during the late 1960s through the 1970s (Norman et al. 1982). These efforts included village-level farm management studies, which greatly enhanced the state of knowledge about farming systems and influenced decisions on research themes and assessment criteria of IAR programs. RERU initiated work on the importance and rationale of intercropping in Hausa farming systems, and was the major antecedent of the FSR/E methodology that subsequently became widely used throughout West Africa in the 1980s (Norman et al. 1979; Gilbert et al. 1980).

The socioeconomics group at IAR played a critical role in the initial phases of maize technology transfer in the area. An improved seed and fertilizer package was successfully tested by an individual Hausa farmer in the Funtua area as part of the ongoing program of technology field testing in the early 1970s. The results were unequivocally positive, and were an important factor behind the decision to include a maize package in the promotional plans of the Funtua Agricultural Development Project. Further, IAR's on- farm work in the 1970s had considerable influence on on-station research in the 1980s. Most of the agronomic trials changed from pure crop to mixed cropping trials (Elemo et al. 1990).

Extension

Efforts to promote improved varieties and practices for maize in the Northern Guinea Savannah date from the 1970s and the first generation of Agricultural Development Projects (ADPs) funded by the World Bank. Among these, the Funtua project was situated in the vicinity of IAR field

Figure 3.11. Nigeria Fertilizer Law



Source: See Annex D.

work that had included maize. The project's initial efforts were able to build upon the considerable body of knowledge of farming systems and experimental results that IAR researchers had assembled over more than a decade. The ADPs were a major factor in the dissemination of improved maize technologies and the consequent expansion in area and production.

Promotional activities, credit, overvalued exchange rates, and direct subsidies all acted to reduce input costs to farmers and encourage their use. Fertilizer consumption has risen dramatically since the early 1970s (see Figure 3.11), and improved maize varieties are now used on approximately 90% of the area planted to the crop in Nigeria (Smith et al. 1990). Federal and state government policies, however, favored control of input production and distribution by public agencies, particularly in the case of fertilizer. Farmers were often unable to acquire their fertilizer needs in the amounts and at the times required. In recent years, however, there has been an expansion in private sector participation in the inputs subsector that will hopefully improve availability. Devaluations and the phasing down of the ADPs has adversely affected the distribution networks and reduced the attractiveness of inputs generally, but a foundation of demand now exists that should continue to expand in the future.

Another important program in the dissemination of improved maize varieties in Nigeria was the National Accelerated Food Production Project (NAFPP), which was initiated in the early 1970s with support from USAID. NAFPP was a collaborative effort involving federal and regional research and extension institutions, and implemented under the terms of a contract with IITA. NAFPP supported on-station and on-farm trials that included minikits containing improved maize varieties. During this period a large number of minikits were distributed throughout the country, which contributed to the dissemination of improved germplasm as well as generally increasing farmer awareness of the potential of maize.

Agricultural Policy

The surge in oil revenues in the mid-1970s enabled the Nigerian government to implement development programs of unprecedented proportions. Although expenditures emphasized the development of urban and industrial infrastructure, the agricultural sector also benefitted through the elimination of taxes on traditional exports, and investments in research, extension, and road networks. Road mileage in the northern states increased fivefold between 1967 and 1980, greatly improving communication (Smith et al. 1990). There was also a major expansion of social services in rural areas.[17]

Government economic development strategy during the oil boom was reminiscent of the rapid industrialization and transformation approaches pursued by Ghana and other countries a decade earlier. Unhappily, the results have been similar. The large increases in money supply over a relatively short time period had predictable effects on wages and prices, particularly in the urban sectors. Nonfarm employment expanded dramatically as did school enrollment. A major shift of labor out of agriculture affected both Nigeria and neighboring countries from whom workers were drawn in large numbers. Total area and agricultural production consequently dropped despite efforts by the federal and state governments to stimulate the sector through a range of programs. Although there was an active private sector, governments still saw themselves as playing the leading role in many areas, including the provision of agricultural inputs.

In 1985, a parastatal fertilizer company, NAFCON, was established and given a monopoly over fertilizer manufacture and imports. One of the sound economic purposes of this move was to maximize local value-added by making use of petroleum by-products. The mistake was making NAFCON a monopoly. Similarly, the National Seed Service was established in 1986 to multiply seed, but it has failed to provide adequate quantities or quality. The agricultural research services continued to produce seed themselves and through outgrowers. Their operating budgets were squeezed by government austerity programs, however, and they were less and less able to produce effectively. Supplies of seed and fertilizer have been erratic, and prices have increased.

As the oil boom faded in the early 1980s, the government resorted to restricting imports as a means of simultaneously encouraging production and saving foreign exchange. In 1985 it banned imports of poultry, wheat, corn, and other coarse grains. The ban on grain imports, together with the overvaluation of the currency, stimulated investments in large-scale, mechanized farms, most of which were hastily conceived, poorly managed, and which have since failed. Devaluations and difficulties in obtaining spares for the machinery progressively reduced the attractiveness of commercial farming during the late 1980s. There was little lasting positive effect on grain production, and prices rose dramatically in 1990 as demand outpaced production. Grain smuggling from neighboring countries has increased.

Policies and conditions have also stimulated the production and consumption of cassava during the past decade, although production statistics are particularly suspect for root crops. Cassava accounts for 40% of the average caloric intake for Nigerians and is possibly the cheapest source of calories. In recent years the combination of population pressures and limited off- farm employment opportunities in the formal sector are making labor more readily available in rural areas than during the oil boom period. These conditions may stimulate intensification and growth in the agricultural sector, given continued progress in economic policy and a peaceful return to civilian rule.

Farm-Level Impacts

The impacts from adopting innovations for maize production must been seen against the

17. Most of these investments were concentrated in towns with populations exceeding 20,000.

Table 3.7. Returns to Labor, Daudawa Village, S. Katsina, 1973-74

Crop	Labor input without traction days/ha	Overall return to labor N/hour	Return to labor; peak labor period (June-July) N/hour
Improved maize	526.3	0.33	1.05
Improved sorghum	400.5	0.17	0.53
Local sorghum	240.9	0.21	0.81
Improved cotton*	516.9	0.07	0.25
Local cotton*	526.3	0.04	0.17

* Cotton prices were low on the world market at the time and have since improved substantially.

Source: Norman, Simmonds, and Hay 1982.

backdrop of the major cross currents of events occurring in Nigeria during the past three decades. From the perspective of a Hausa farm family living in the area covered by the Funtua ADP in southern Katsina State, the events of the mid-1970s onward provided great opportunities tempered by considerable frustration and disappointment over inputs, prices, and weather.

Mallam Abdullahi of Makarfi village in the Funtua project area is a small farmer in terms of his own land. He farms 2.4 ha of prime fadama land,[18] of which 1.6 ha belongs to him. Mallam Abdullahi is also a client of a middle-sized farmer, from whom he rents another 32 hectares. He grows maize and sugar cane in rotation, with cowpeas relayed into the maize crop at the end of the season. In 1991 he bought fertilizer at twice the official price in order to have it on time. He uses family labor, but hires workers on a task basis. The hired workers are mainly local farmers who lack enough cash to farm beyond the subsistence level themselves, or young urban poor from Kano and Katsina towns. Mallam Abdullahi grows both local and improved varieties. He prefers the former for eating, but the latter is less risky and higher yielding.

18. Based on an interview conducted by L.C. Phillips, September 1991, in Funtua district.

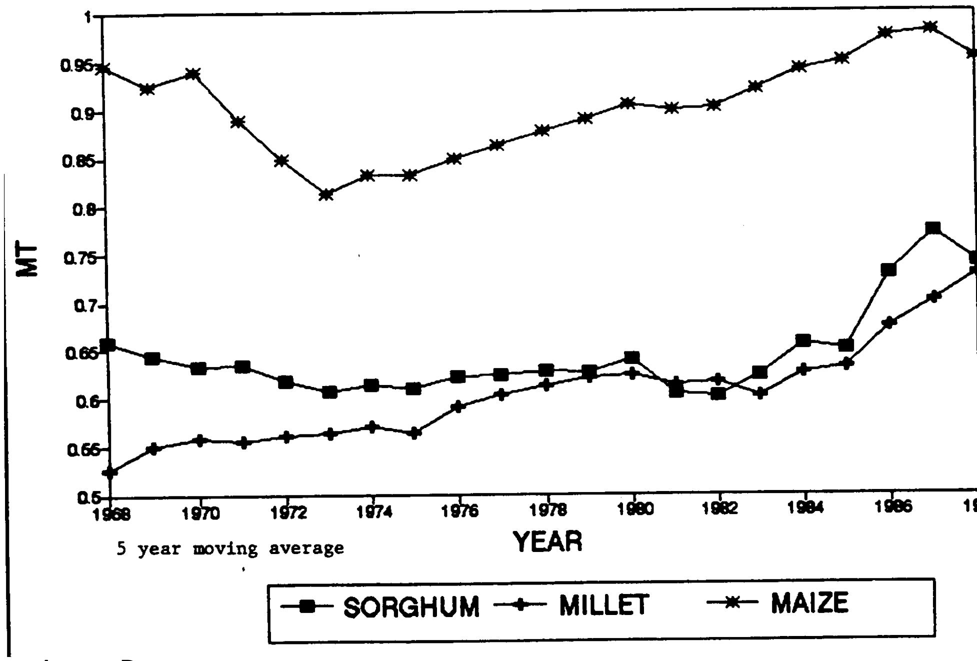
Factor Productivity and Resource Allocations

For farmers in the Northern Guinea Savannah like Mallam Abdullahi, maize was a relatively minor crop prior to the mid-1970s. The new varieties and the promotional efforts of the Funtua ADP produced major changes in farmer perceptions, leading many of them to substitute maize for sorghum and millets, the dominant coarse grains produced in the area. The area devoted to the traditional cash crops (cotton and groundnuts) also declined during this period. The returns to labor for maize were superior to the other crops in the system (Table 3.7).

Although improved maize requires more labor than sorghum, the Agricultural Extension Service found that farmers both adopted improved seed and followed extension advice on planting and weeding time (Igodan et al. 1987). This suggests that labor is not currently the constraint it was once thought to be.

The yields of all coarse grains improved, particularly in the late 1980s (Figure 3.12). However, the area devoted to sorghums and millets declined during this same period. Sorghum and millet were possibly replaced by other commodities or fallow land in areas that experienced recurring poor rainfall, especially in the northern border regions. Overall, the existing statistics suggest a decline in total area devoted to coarse grains. A major portion of this reduction represents a contraction of

Figure 3.12. Nigeria Coarse Grain Yields



Source: See Annex D.

commodities other than maize, and is likely a function of a complex set of factors including erratic rainfall, off-farm activities, and relative prices. The fact that maize area expanded despite the overall decline in cropped area in the zone indicates the importance of maize innovations in the minds of many farmers.

Increased cash revenues led farmers to invest in animal traction equipment and/or use hired labor. Labor was reported to be a major constraint to agricultural production in Hausaland during the sixties and seventies (Hill 1982; Norman et al. 1982). By 1989, however, only 19% of the villages in Smith's study (1990) reported labor shortages, which is attributed to the widespread adoption of oxen for land preparation and weeding, and also to the availability of migrants from neighboring countries. Improved availability of labor is credited with better crop maintenance and an expansion of the area cultivated per household.

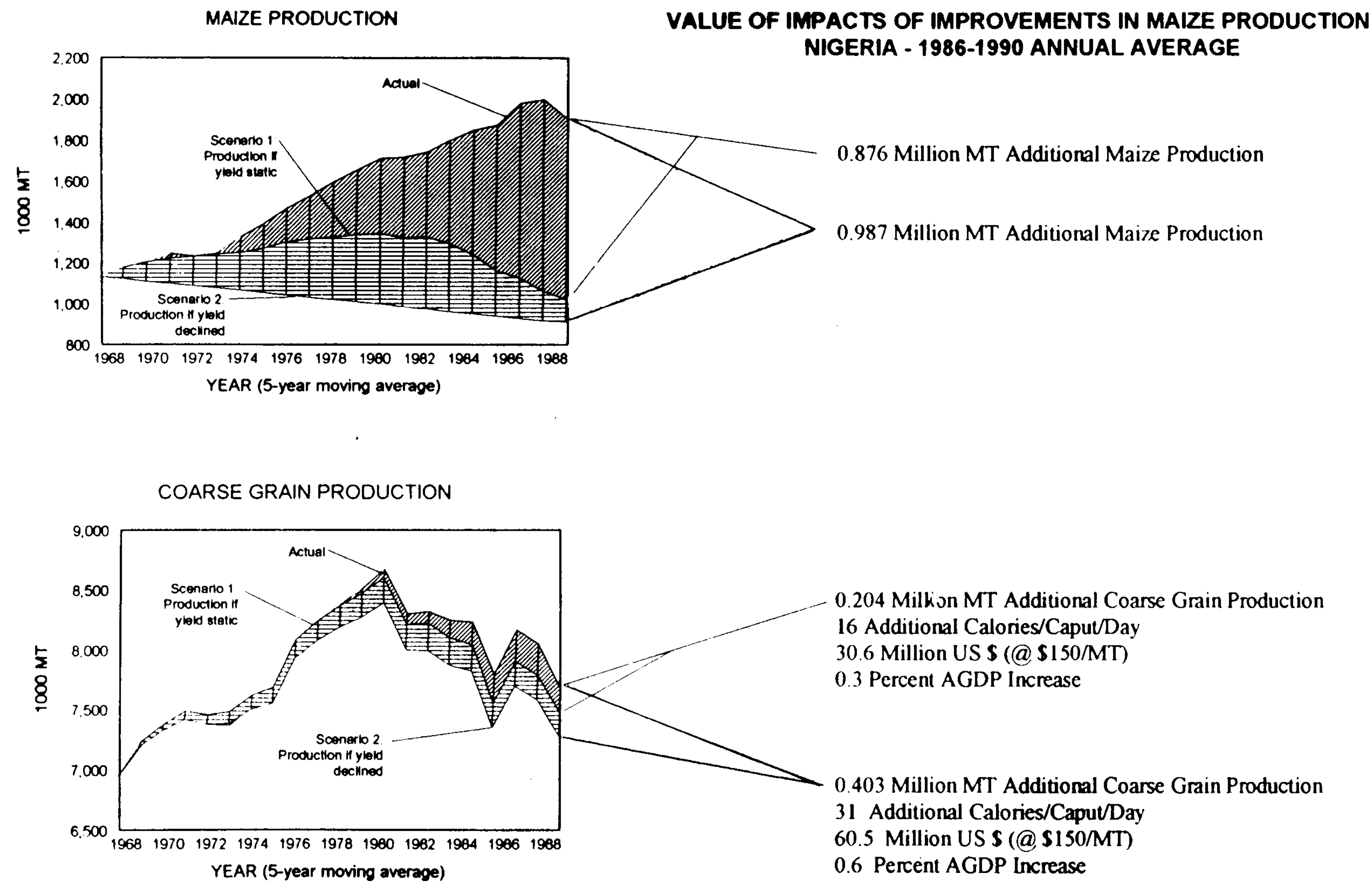
Hausa farm families generally rely on nonagricultural activities to earn income during the dry season. The expansion in maize production has encouraged successful farmers to diversify into trading, a prestigious occupation in Hausaland.

Consumption

Traditionally, basic farmer strategy has meant growing enough food (primarily millet, sorghum, and cowpeas) to meet the family's needs; cash crops of groundnuts, sugarcane, and cotton were of secondary importance (Norman et al. 1982). The practice of growing these crops in mixtures is consistent with the goals of both profit maximization and food security. Until the mid- seventies maize was primarily a garden crop that ripened early and provided relief from the "hungry period" toward the end of the farming season (August/September).

Maize expansion was initially driven by its potential as a source of cash through sales to established southern markets. The taste for maize has developed only gradually in the northern states as maize meal began to be mixed with sorghum and millet in the traditional gruel (tuwo). This development marginally improved the protein content

Figure 3.13. Nigeria Maize and Total Coarse Grain Production, with and without Technological Change



Source: See Annex D.

of diets, particularly among women and children. Increased maize production has also expanded the crop's use as a feed, particularly for poultry production aimed at satisfying urban demands, and as an ingredient for the brewing of beer.

Equity

The major expansion of commercial farming in the northern states was given added impetus by the grain import bans and overvalued exchange rates of the mid- 1980s. Although new entrants made extensive use of the new technologies, many of these operations subsequently failed. Southern Katsina possesses a long-standing group of larger farmers, although the area has been relatively densely populated and farmed compared to the Southern Guinea Savannah where much of the expansion of commercial farming took place. Wealth differences among farmers are a well-established facet of rural areas and it is unlikely that maize innovations have changed this situation. At the same time, the basic seed fertilizer technologies were usable by the majority of farmers, although access to inputs was uneven.

Zonal Impacts

Historically, maize has been more important in the production and consumption patterns of southern Nigeria than the north. Innovations for maize have been instrumental in reversing this relationship. The savannah zone rapidly became the prime maize-producing region, supplying the markets of the big southern cities. The production in the north was stimulated directly by the diffusion of improved technologies and the availability of established markets in the southern states. Without the introduction of improved varieties, maize production would most likely have remained primarily a subsistence activity in the north, contributing less than 10% to the total national maize production. The improvements and expansion in the savannah zone have resulted in an estimated 60% contribution to Nigeria's total maize production. At $150 per ton, this amounts to a $165 million annual income for the savannah-belt farmers.

National-Level Impacts

The national aggregate impacts of the spread of maize innovations are illustrated by comparing the actual trend with two "without technological change" scenarios (Figure 3.13). Scenario I uses a static 1966-70 maize yield with area as a fixed proportion of actual total coarse grain area. According to this scenario, the technological innovations that have resulted in improved yields over this period account for an average additional 876,000 MT of maize production or a net increase of 204,000 MT of coarse grain production annually. Accordingly, Nigeria has saved US$30.6 million on food imports. More modest, but still significant, are the contributions to daily caloric intake (16 calories per capita) and the 0.3% increment in AGDP.

Scenario II is even more dramatic. This scenario assumes that farmers have not cultivated more area in maize from the 1966-70 average, and furthermore that maize yields decline 1% annually due to disease and decreased soil fertility. Technological innovations in this scenario account for an additional 987,000 MT of maize production (403,000 MT of coarse grain production). The savings in food imports doubles to US$60 million, and the contributions to daily caloric intake (31) and AGDP (0.6%) are also double those in the first scenario.

SENEGAL[19]

The cases of Senegal and its neighbor, The Gambia, illustrate how a relatively minor crop can grow rapidly in importance with a combination of the right conditions and innovations.[20]

19. This section is a summary of the MARIA case study for Senegal prepared by William Roberts.

20. An assessment of the impact of maize research and development efforts in The Gambia is the subject of a separate study by Musa Mbenga which is not formally part of the MARIA study. Source: Fay and Bingen (1989:4).

Senegalese maize production has increased on average by 2.8% annually since 1980, significantly outpacing other staple foods and traditional cash crops. This progress has taken place in different parts of the country in a variety of farming systems, including rainfed production in the southern and central portions of the country and irrigated systems in the drier eastern and northern sections.

The primary production sector (agriculture, livestock, fishing and forestry) averaged 24% of GDP during the 30 years after independence. Agriculture has decreased as a proportion of GDP since 1978. In 1977 agriculture accounted for 18.4% of GDP while in 1984 it accounted for only 7% (due mainly to bad weather). By 1990 agriculture had increased to 8.3% of GDP (USAID 1991). During the 1980-87 period nearly one-half of the country could not produce rainfed crops due to decreasing rainfall. Despite environmental constraints, however, it is expected that agriculture (along with the nonagricultural informal sector) will absorb the majority of new entrants in the labor force since opportunities outside of agriculture are limited (Berg 1990).

Senegalese farmers produce approximately 52% of the nation's food grain needs. Country food needs are calculated using FAO standards for an average individual consumption of 170 kilograms of grain per year. Grain imports account for 40% of national needs, and food aid covers the remaining 8%. Between 1969 and 1985 cereal imports (primarily rice and wheat) increased from 260,000 to 450,000 MT per year, exceeding the rate of population growth for the same period (Faye and Bingen 1989). By 1988 Senegal imported 461,000 MT of cereals and received 109,000 MT in food aid (World Bank 1990a). It is estimated that by the year 2000 Senegal will require some 1,700,000 MT of grain to feed its population.

Since 1970, Senegalese farm households have been steadily pressured by drought, population growth, state disengagement, and structural adjustment. During this same period, the area devoted to maize production has more than doubled from an annual average of 44,000 hectares between 1970-75 to an annual average of 102,000 hectares between 1985-90. At this time the average annual maize yield increased 67%, from 760 kg per hectare to 1266 kg per hectare. The maize surge came in the mid-1980s when the land area devoted to maize increased to over 100,000 hectares, approximately 4.5% of the 2.2 million hectares cultivated annually. The annual rate of increase in maize production since the mid-1980s has been only slightly lower than the population increase (both rates average 2.8%). The discussion focuses on southern Senegal (see Figure 3.14) where rainfed agriculture and maize cultivation is concentrated.

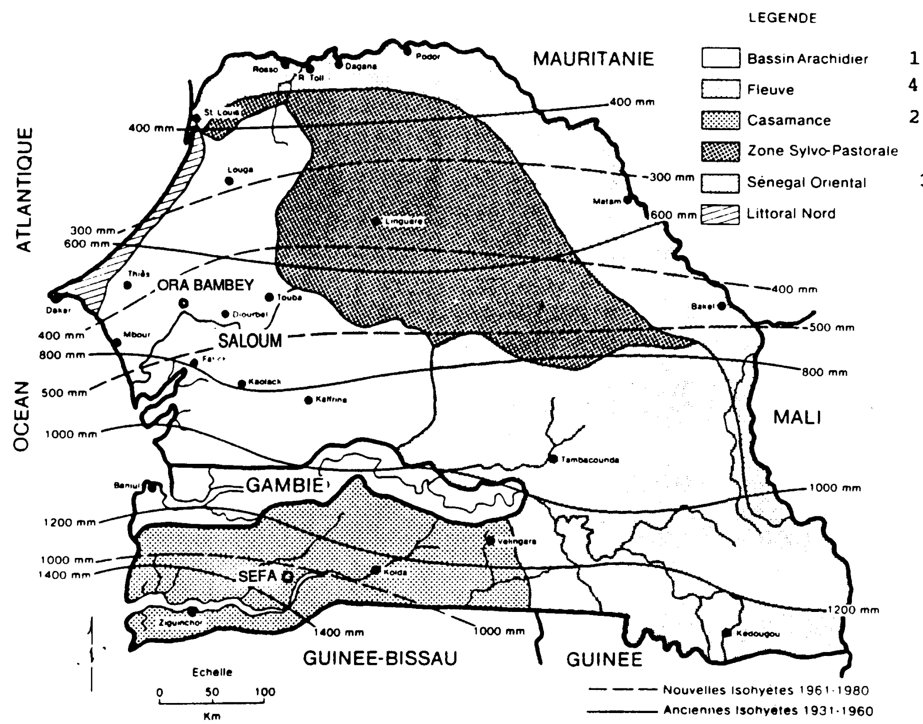
Overview of Factors

Farming Systems

Rich and poor farmers can be distinguished in rural Senegal, but there is no estate or commercial sector of great importance comparable to that found in East and southern Africa. Households produce a major portion of their own food needs, particularly sorghum and millet, but a high percentage rely on the market for much of their rice and all their bread, which they consume regularly.

The major farming systems found in southern Senegal are usually associated with the predominant ethnic group of a particular area. The Mandinka and Wolof farming systems traditionally grow millet and sorghum as food crops in the upland fields, with peanuts and cotton as the major cash crops. Animal traction use is widespread in the upland fields, which are managed by men. Men generally receive access to upland fields through community legitimized tenure claims. Land is less of a constraint to agricultural production than labor. More well-to-do farmers with large, well-equipped (traction) households often hire labor as needed. The agricultural wage labor pool consists of poorer farmers, migrants, and members of clubs.

Figure 3.14. Map of Senegal



Source: Fay and Bingen (1989 : 4).

Maize production in Senegal is primarily a male-managed activity, while women are generally concerned with the local marketing, processing, and preparation of the grain. Women have traditionally cultivated lowland areas in rice and dry season garden crops.

Senegalese farmers cultivate maize on two different types of fields. Small quantities of maize are grown in well-manured fields adjacent to villages and serve as an important food source during the "hungry period." Over the past 20 years, however, maize has expanded into outlying fields, replacing peanuts and other coarse grains.

The decline in rainfall has reduced the scope for rainfed crops in northern areas. Decreased rainfall and increased wood use for fuel and construction needs have degraded northern areas and intensified competition for land in south. Reduced vegetation cover has contributed to a general deterioration in soil fertility in many areas. In response, farmers have shifted to short-cycle cereals, and rely on manure and inorganic fertilizer to maintain soil fertility for cultivation.

Throughout Senegal, livestock represents farm capital and savings. Animal traction has freed labor for other enterprises, and is associated with substantial migration out of rural areas and the expansion of rural nonfarm activities. Lower rainfall and vegetation has also reduced the trypanosomiasis challenge and improved livestock health. This has facilitated the expansion of animal traction in southern Senegal and The Gambia.

Research and Extension

As a commodity of secondary importance in Senegalese farming systems, historically maize has not received priority attention in either research or development efforts compared to the principal upland crops and rice. Maize research is included in the responsibilities of the upland cereals programs in both Senegal and The Gambia, but emphasis has been on sorghum and millets. Research on maize has followed rather conventional lines in its approach to varietal improvement and other themes (time of planting, spacing, etc.).

Improved varieties and hybrids were developed at the Sefa station in Casamance in the 1960s by French researchers using materials from France, the United States, Mexico, and C te D'Ivoire (Jacquot 1969; Durovray 1976). Breeders focused on developing open- pollinated varieties. Periodically, state-sponsored projects made hybrid maize such as JDS (yellow) and BDS (white) available to farmers at subsidized prices. Criteria for varietal selection included yield, time to maturity, grain color and texture. Additional maize research on agronomic and cultural techniques provided information for creating extension packages to farmers according to socioeconomic factors associated with "levels of cultivation."

The Senegalese research system deserves credit for early FSR/E activities. The Unit Experimentales (UE) agents in Sine Saloum worked closely with farmers and demonstrated what was entailed to profitably cultivate maize. UE activities became a formal part of the Senegalese Research Institute's structure, but was generally not well-linked to the commodity improvement programs. Competition for resources led to periodic tension between researchers and was an obstacle to both research and extension (Faye and Bingen 1989).

Maize requires more inputs than either millet or sorghum, and the provision of inputs has been the responsibility of public sector agencies since before independence. Despite efforts to liberalize arrangements under the New Agricultural Policy (1984), input supply remains problematic. Farmers have used second- and third-generation seed from hybrids because of the difficulty in replacing seed annually. In other years when there was an intense effort to produce hybrid seed, not all that was distributed was planted as seed. Research for output markets (processing and consumption) has received much less attention than varietal development despite the fact that output markets have been referred to as an obstacle to further expansion of maize.

Projects with a new maize technology component (research, extension, input/output delivery) have been most prominent in four of Senegal's five major agroecological regions: the Sine Saloum peanut basin, Casamance, Senegal Oriental, and the Senegal river valley. Sine Saloum and Casamance are discussed later in detail as these regions have witnessed the most dramatic impacts from new maize technologies connected with projects.

Evolution of Agricultural and Food Policy

Following independence, Senegalese development plans emphasized that the state take a leading role in the improvement and transformation of the agricultural sector. Cash crop production of peanuts and cotton were given priority, and imports of cheap rice from Asia continued. The government monopolized input and output markets, which led to price distortions favoring urban consumers instead of rural producers. Drought and rapid population growth resulted in an upward spiral of food imports, and created conditions that were only partly relieved by international food aid efforts.

In the New Agricultural Policy (NAP) in 1984, the Senegalese government ended the old strategy of producing and exporting groundnut products in order to finance cereal imports. The Seventh Development Plan in 1985 and the Cereals Plan in 1986 outlined the following goals: (1) increase the cereals self- sufficiency rate from roughly 50% to 80% by the year 2000 (this will come primarily from an increase in rainfed crop yields and increasing the amount of cultivated, irrigated land); and, (2) transfer economic activities of input and product marketing from the state to the private sector.

Progress in implementing NAP has been slow, at best (Berg 1990).

Farm-Level Impacts

Senegalese farmers have been motivated to expand maize production over the past 20 years because it helps meet their dual goals of household food consumption security and increased income earning possibilities. To accommodate increased maize production, farmers have reduced areas devoted to groundnuts. Expanded maize cultivation has been facilitated by adoption of other farm technologies, especially animal traction equipment.

Changes in Factor Productivity

Adjustments in resource allocations, particularly land and labor in different parts of Senegal, clearly has involved more than technological change for maize. Maize remains very much a secondary crop throughout the country despite a major increase in its relative importance since the 1960s. Changes in the productivity of maize cultivation have occurred alongside major shifts in cropping patterns and resource allocations between agricultural and nonagricultural activities. These shifts are the result of technological changes, especially the spread of animal traction, and factors such as environmental deterioration and an evolving policy context. Improvements in the productivity of maize cannot be attributed to research and development alone.

Maize produces much higher yields per unit of land and labor than millet and sorghum, and improved maize varieties have a 30% higher return to labor than traditional or unimproved maize seed (Martin 1988; Benoit-Cattin 1986). As Table 3.8 shows, maize gives good returns per hectare for average rainfall using low technology.

Maize research has helped Senegalese farmers achieve significant increases in maize productivity and production. During the 1980s, returns to maize production increased relative to other crops because of concurrent increases in maize prices and yields. Table 3.9 shows returns to labor and land for different crops in different areas of the country. Maize is attractive compared with other crops in terms of returns to both land and labor.

Changes in Resource Allocations

Maize innovations have had the greatest impact on fields where groundnuts, millet, and sorghum were previously planted. These areas have been the target of extension efforts to expand and diversify maize production in the 1980s in response to government- supported efforts to increase cereal self-sufficiency. The expansion into outlying fields is partly due to improved prices for maize compared with the traditional groundnuts cash crop. However, improved maize varieties are also cultivated throughout the country on the heavily manured household fields where local varieties once predominated.

Impacts on Consumption

Rural Senegalese consumption patterns have shifted towards a varied diet as a result of consumer demand for, and access to, food imports such as canned meats, bread, and imported rice (Kelly et al. 1991). There are substantial regional, ethnic, and seasonal variations in maize consumption throughout the country. In general, the closer a village is to the capital of Dakar, the greater the reliance on food purchases or food aid. In more distant southern regions the proportion of farm production that meets home consumption requirements is higher. Maize consumption in the southern areas is highest in the postharvest period when it accounts for 60-70% of total cereals consumed.

Regional Impacts

Impacts in the Casamance and the Sine Saloum groundnut basin are compared for illustrative

Table 3.8. Indicators of Agricultural Productivity in 1981 and 1989

Producer income per hectare for:	1981	(000 CFAF)	1989
Oil peanuts	22.8		31.0
Millet	19.3		21.2
Maize	32.2		40.9
Cotton	41.6		52.8
Rice	41.0		83.0

Source: Kelly and Delgado, 1991:112.

Table 3.9. Net Financial Returns* to Land and Labor in Southern Senegal

Geographic Area and Crop	CFAF/hectare	(000 CFAF)	CFAF/man day
Southeastern Peanut Basin			
Peanuts	44.0		1.3
Millet and sorghum	31.8		0.9
Upper Casamance			
Irrigated rice	122.5		0.7
Maize	63.2		1.2
Senegal Oriental Maize	95.4		1.9

*For average rainfall and low-intensity technology.

Source: Kelly and Delgado (1991:114).

purposes. The French established agricultural research in the Sine Saloum during the colonial period. A succession of well-financed parastatal organizations promoting agricultural production has made it the most highly developed agricultural region in Senegal. The area has a high population density and a thriving network of weekly markets and boutiques in rural villages. As a result, the activity level of merchants makes maize commercialization relatively easy compared with Senegal Oriental and Upper Casamance where production zones are more isolated. The maize market in Kaolack involves producers and local collectors in rural areas, with larger-scale, trader-transporters buying from local merchants in the town market (Agel and Yung 1989).

The UE worked directly with farmers in agricultural research and extension in off-station fields in the Kaolack area. A maize-breeding program was also established at Bambey in 1971 to extend maize production to the regions of Senegal north of The Gambia. Extension agents worked closely with farmers; fertilizer and urea applications were recommended and, by 1975, fertilizer use and the number of improved harvest storage areas constructed reached their highest levels.

The Casamance region has greater ecological and ethnic diversity. Nevertheless, maize production and productivity have improved as a result of research and extension in this area. The graph shows a 231% expansion in the area of cultivated maize for Casamance, from an annual average of 17,400 hectares in 1970-75 to 40,200 hectares in 1985-90. Expanded production and improved productivity accounted for an average annual increase of 33,800 MT of maize during the 1985-90 period above the 1970-75 period with a market value of 2.4 billion CFAF. The Casamance has a small deficit area for maize and total cereals production relative to its population (Martin 1988). Maize accounted for approximately 15% of regional cereals supply from 1983- 85. In comparison, the area for peanuts, millet, and sorghum decreased less than 2%. There was an 8% increase in the total area cultivated for these three crops during this period. Casamance farmers have chosen to plant maize in place of other crops within their highly diversified crop regimes because it helps meet both food and income needs.

National-Level Impacts

By the time maize production and productivity statistics are aggregated at the national level, many of the more significant impacts discussed earlier are not as clearly visible. Figure 3.15 illustrates the significance of maize technology adoption through production calculations using the scenarios described in Chapter 1. According to Scenario I, maize yields would remain at the 1966/70 level and, between 1986-90, an average 80,000 MT of maize worth US$11 million would not have been produced each year. The difference is even greater for Scenario II, which assumes a 1% decline in maize yield per year. During 1986-90, an average of 90,000 MT of maize worth US$13 million would not have been produced. Even though Senegal must continue to import food to feed its population, new maize technology has reduced imports of coarse grains between US$7 and $8 million annually.

The second graph in Figure 3.15 shows the overall secondary importance of maize compared with millet and sorghum production. However, per capita maize use has climbed 80% from an annual average of 9.2 kgs/capita in the period 1976/80, to 16.5 kgs/capita for the period 1986/90. These figures include maize used for both animal and human consumption. Maize used for animal feed, primarily poultry, has increased 144%, from an average of 6,500 MT for the 1976-80 period to 15,900 MT during 1986-90. Human maize consumption in this same period increased 135%, from 48,300 MT to 113,300 MT (USAID 1991).[21] Maize consumption patterns, as described in the section on farmer household impacts, vary significantly for season, ethnic group, and region.

With more favorable conditions, Senegalese farmers could have further expanded maize production and improved productivity. For example, the CFAF in Senegal is overvalued, thereby making the cost of Senegalese maize production high relative to imported maize for poultry feed. Poultry feed requirements have been estimated at 15,000 MT per year.

Likewise, improved input markets, particularly for seed and fertilizer, could increase maize productivity. Increased maize production that is competitive with the price of maize in neighboring countries could possibly have led to maize exports and subsequent gains in revenue for both farmers and the state.

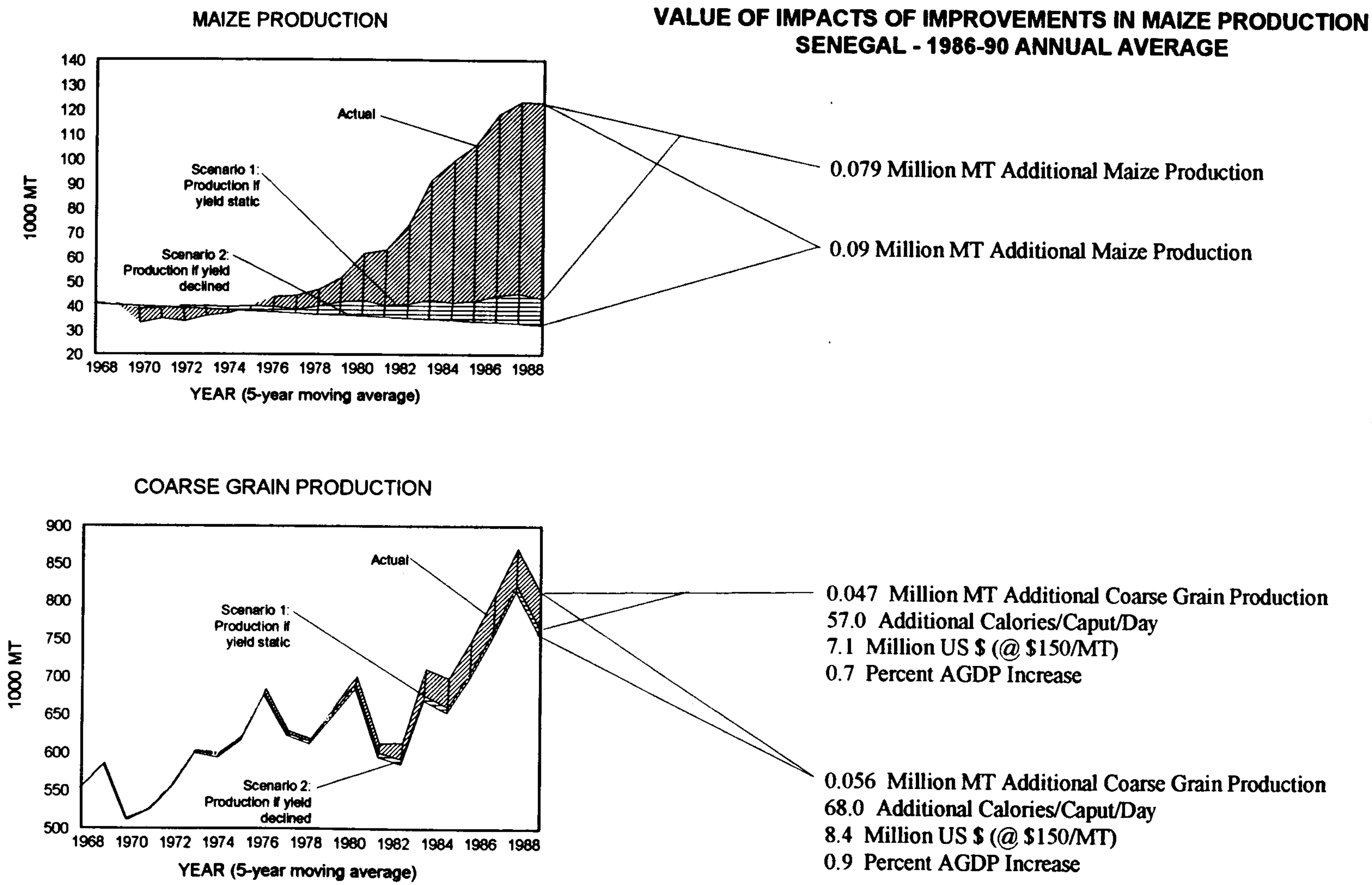
ZAIRE[22]

Zaire is the second largest country in Africa, with a population of 36.6 million in 1990, 70% of which is employed in agriculture. Its 1990 GDP was US$5.6 billion, 30% generated by

21. These maize figures include Senegalese production, food aid, and all imports.

22. This section is a summary of the MARIA case study for Zaire prepared by Lucie Colvin Phillips and William Roberts.

Figure 3.15. Senegal Maize and Total Coarse Grain Production, with and without Technological Change



Source: See Annex D.

agriculture and 20% by mining. Over 200 ethnic groups live in a wide range of local ecologies within the 2.4 million square kilometer national territory. Zaire contains an abundance of natural resources, including large areas of unoccupied arable land, extensive forest reserves, valuable mineral deposits, and extremely high hydroelectric potential. Like other African nations, Zaire includes great socioeconomic diversity; a small proportion of the population is very wealthy while the majority are extremely poor.

Zaire has been beset by more than 30 years of civil unrest, perverse policies, abuse of power, and gross mismanagement since becoming independent in 1960. Towns and cities have grown rapidly although employment opportunities in the modern sector are limited, and services and general conditions in urban areas have deteriorated. Rates of infectious disease remain high, reducing productivity, but poverty limits the extent to which people are able to find treatment. In spite of major internal problems, Zaire hosts large numbers of refugees fleeing even worse conditions in neighboring countries.

Despite these adverse conditions, which seriously constrained research and development efforts, the National Maize Project (PNM) and the North Shaba Project (PNS) were able to develop, test, and extend innovations for maize during the 1970s and early 1980s. These efforts substantially increased national production from approximately 400,000 MT in the early 1970s to 750,000 MT in the late 1980s (USDA 1989/90). National maize yields and area increased by average annual rates of 1.3% and 2.3% respectively during this same period. The yield improvement, together with extension and marketing programs, encouraged farmers to plant maize on a large scale as a cash crop. Maize production has been growing steadily, while other areas of the economy have experienced stagnation or decline.

The area selected for the case study is the northern Shaba region where PNS operated between 1978 and 1984 (see Figure 3.16). The area was also served by PNM, which was assisted initially by CIMMYT (1971-1981), and subsequently by IITA (1985-1991). Farmers in the PNS project area occupied lands that had been identified as a potential grain basket for the copper belt since the 1920s.23 PNS extension workers lived in villages designated as farmers' centers, and provided participant farmers with improved seed for demonstration plots. The extension activities coincided with PNS improvements to roads, increased numbers of vehicles, and higher official producer prices. As a result of improved market opportunities, both traders and farmers had incentives to increase their activities.

Overview of Factors

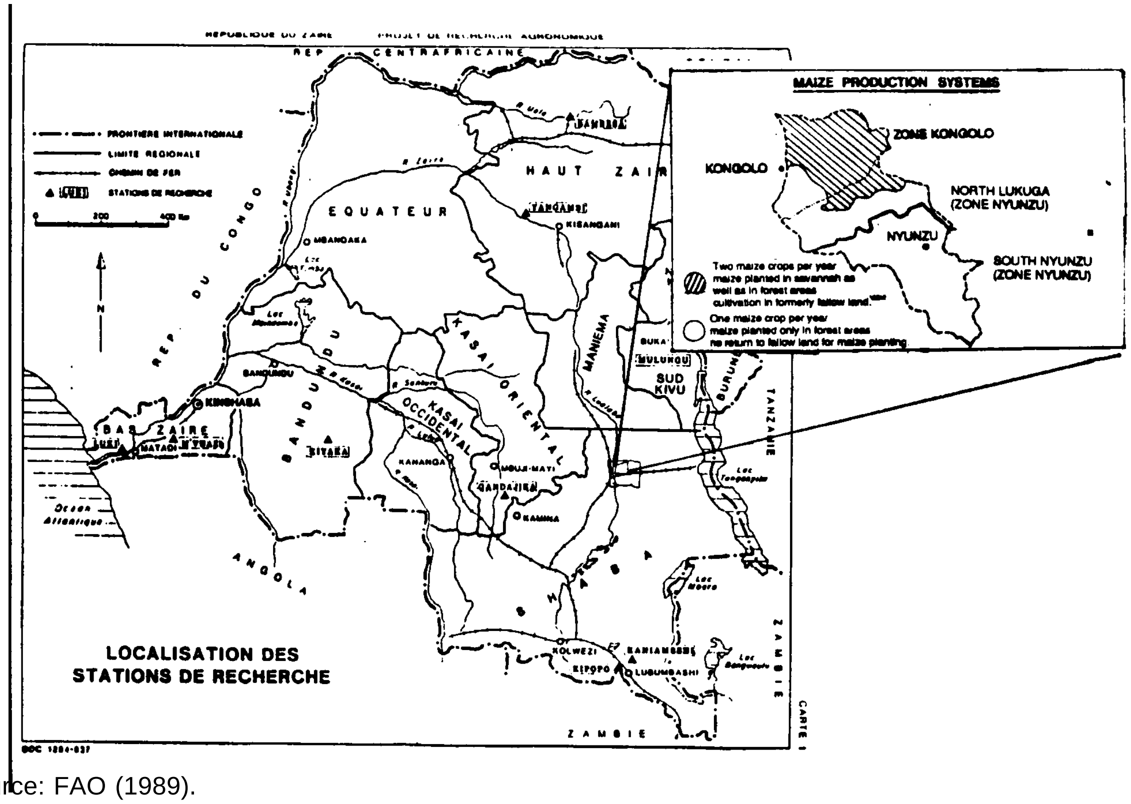
Farming Systems

Maize is the most important cereal crop in Zaire and, after cassava, the primary staple for Zairians. It is cultivated throughout the country and consumed in preparations using maize flour either by itself (bunga) or mixed with cassava flour in making pukari. Occasionally, it is also boiled or roasted on the cob. In the forest areas, low-density populations plant maize as part of their complex, intercrop-relay farming practices in which cassava is central. The prime maize growing areas are in the southeast of the country where altitude ranges between 900 and 1500 meters and rainfall averages 1000-1900 mm from October through May.

In Kongolo and Nyunzu districts of Shaba where PNS operated, farmers distinguish between forest and savannah fields. Kongolo-zone farmers live in a wetter, more densely populated area and produce a wider variety of crops

23. It was mining interests which encouraged maize farming in North Shaba and Kasai rather than South and South-East Shaba despite the better growing conditions and closer proximity to the markets offered by the latter areas. Union Miniere in particular sought to discourage potential competition for labor (Hart 1993).

Figure 3.16. Zaire and Project North Shaba



Source: FAO (1989).

than Nyunzu farmers to the south who farm in drier forest and savannah areas. Kongolo farmers commonly produce two maize crops per year, with maize as one component of a system that includes cassava, rice, groundnut, vegetable, condiment, and fruit food crops, in addition to cotton and tobacco cash crops. Farmers maintain oil palms through their crop rotations. The trees help protect and enrich the soil during the five-year fallow period while providing farmers with oil, palm wine, and construction materials. This farming system reportedly requires lower labor inputs than the farms cultivated in drier forest and savannah areas to the south (USAID 1982). Women in Kongolo have their own fields for maize and other crops.

The Nyunzu zone in the south is more sparsely populated. Male farmers "follow the forest" to produce an annual maize cash crop. Fields are cultivated for about 3 years after clearing, and subsequently abandoned as savannah. Men commonly live at their farms for part of the year, while other family members remain in the villages. Women produce the majority of food crops on the savannah land including a single maize crop often planted after cotton and followed by cassava or a groundnuts/cassava sequence. In Nyunzu, oil palms are usually found within the village area rather than the outer fields that are part of the crop rotation system. Nyunzu farmers, with their migratory farming patterns, appear to be converting forest land to savannah as a result of their cropping practices.

The principal constraint to agricultural production is labor. Farmers gain access to labor from their extended family members and neighbors. In some cases more well- to-do farmers, including sultanis (chiefs), engage pygmies, especially to clear land (Blakely 1979). Shaba farmers do not use animal traction.

Research and Extension

The most important contribution of maize research for the Zairian farmer has been the development of new varieties that produce higher yields than local varieties when grown under the same conditions. The varieties incorporate disease resistance, short stature (less susceptibility to lodging), and considerably higher yield potential compared to local land races.

Prior to 1960, maize research in Zaire was the responsibility of the Institut National pour l'Etude Agronomique du Congo Belge et du Ruanda Urundi (INEAC), which was established in 1933.24 Independence and subsequent civil wars effectively ended INEAC's operations throughout most of the country and, by the mid-1960s, virtually all of the expatriate research and senior administrative staff had left. INEAC was succeeded by the Institut National pour l'Etude et Recherche Agronomique (INERA).

In 1971 the Ministry of Agriculture approached the USAID mission in Kinshasa for assistance in revitalizing efforts to improve maize production. The mission put the Ministry in contact with CIMMYT, and a project agreement—Projet National Maiz (PNM)—was concluded that same year. A team of technical advisors from CIMMYT were posted to PNM, an association that continued for 10 years through to 1981. PNM expenses, including CIMMYT participation, were supported almost entirely from government sources for the first 7 years of the project. USAID support was limited to a portion of the training during this initial period. PNM local staff included 35 Zairian researchers, several of whom received postgraduate training under the project. Considerable progress was made, partly because of insulation from both USAID and Zairian administrative politics (Hart 1993).

CIMMYT wanted to conduct research that would benefit poor farmers, and developed OPVs that performed well in low-management farming systems. Their research themes were similar to those that guided INEAC research; namely, develop and adapt maize varieties that were insect resistant, produced high yields under Zairian ecologic conditions, and met consumers' tastes (Mbuki 1977). The breeding program, however, was marked by disagreement among researchers over hybrids. Hybrids generally have a higher potential under a range of conditions as was demonstrated by the experience with Zaire's neighbors in East and Southern Africa. But CIMMYT felt it was impossible for seed to be successfully produced and distributed on a regular basis due to the lack of infrastructure, credit, and delivery systems that characterized prevailing conditions in Zaire (Hart 1993). Similar problems with fertilizer meant that most farmers would not realize most of the benefits from hybrids and might be worse off if new seed was not available for every season.

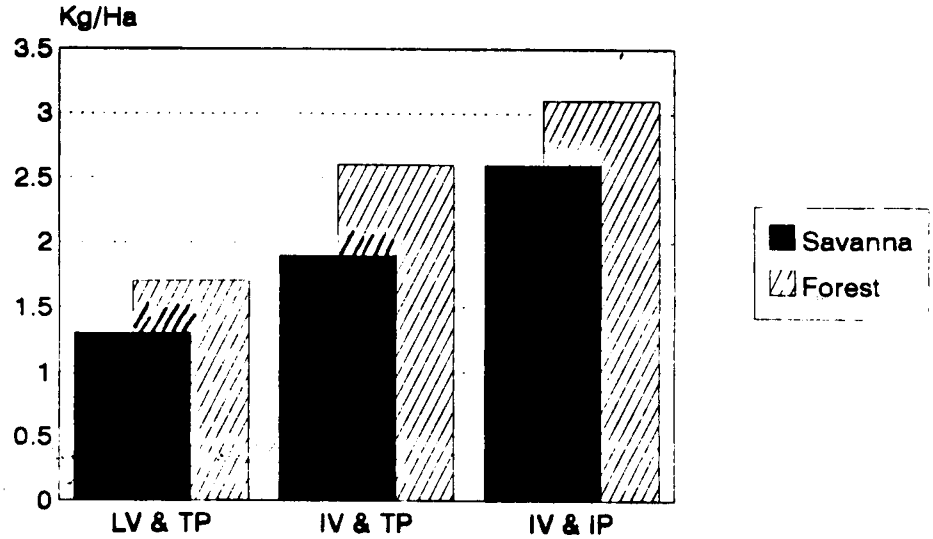
After the CIMMYT bilateral involvement in PNM ended in 1981, there were serious discontinuities in the maize research program. IITA involvement began in 1985, and focused on disease resistance. Work on hybrids was revived in 1987 at the Maize Research Center at Kisanga with support from Yugoslavia. The Center produced and diffused hybrids derived from Zimbabwean SR-52 that were reputedly of poor quality (Nzeza 1991).

Yields of over 6 MT per hectare were achieved for improved OPVs on-station (Brockman et al. 1990).25 An early effort at on-farm maize trials by PNS demonstrated the

24. In its day INEAC was arguably the strongest agricultural research institute in tropical Africa and was responsible for the development of new varieties and practices, primarily for plantation crops (e.g., oil palm, cocoa) that are still in use today. Maize was not a high priority, but some research on the crop did form part of efforts to improve and standardize indigenous farming systems (Miracle 1966; Johnston 1958).

25. Yields of PNM I and Shaba I were consistently greater than 6 MT in both on-station and on-farm trials, and were between 4 and 6 MT for Kasai I and Salongo OPVs (Hart 1993).

Figure 3.17. Farmer-Managed Maize Trials, Project North Shaba, 1970



Participating farmers were given Kasai I seed to compare against their local varieties on forest and savannah demonstration plots. The forest yields were superior to the savannah yields in each case. The use of improved varieties averaged a 40% yield increase over local varieties using traditional practices. An additional 30% yield increase was obtained when farmers followed PNS improved maize cultivation practicies such as higher crop density and row planting.

Source: Barclay, Poulin, and Sargent (1980:87).

improved yields achieved by Kasai I OPV (Figure 3.17). Participating farmers were given Kasai I seed to compare against their local varieties on forest and savannah demonstration plots. The forest yields were superior to the savannah yields in every case; improved varieties averaged a 40% yield increase over local varieties using traditional practices. An additional 30% yield increase was obtained when farmers followed PNS improved maize cultivation practices including higher plant populations and timely weeding.

Agricultural Policy

Zairian farmers have endured a history of coercion and exploitation begun by the Belgian colonial administration and followed by the postindependence government of president Mobutu Sese Seko. Farmers in North Shaba, for example, were required to cultivate cotton since the 1930s. Wariness and weariness describe the "state of mind" for many Shaba farmers, who have nonetheless responded positively to demonstrations of increased productivity for new maize varieties by acquiring and planting improved seed. For nearly two and half decades the national policy context favored urban consumers at the expense of rural producers. Zairian food policy in the 1970s was characterized by Mbuki (1977:256) as being:

> designed to provide cheap food items for urban workers and to maximize industrial surpluses that can be generated by low salaries induced by cheap food. In this, Zaire is just one of many countries using indirect taxation of agriculture to generate the development of other sectors of the economy ... price policies, as they existed in 1974-75, appeared to create negative incentives for increased maize production.

Zaire imported more than 100,000 MT of maize in 1969, and authorities feared that by 1980 the need would be 500,000 MT.26 In response, the government strongly supported the initiation of PNM and agreed to provide all the funding for the CIMMYT contract. Unfortunately, the initial commitment was not matched by consistent action in the late 1970s, and the financial contributions from the government progressively waned. Considerable efforts were required by PNM management to access promised support. The USAID grant proved critical in preventing serious interruptions of activities caused by delays in receiving government funds (Wedderburn 1991).

The primary target groups for PNS and PNM were small, low-resource farmers.27 This focus was a notable exception to the dominant government approach to agriculture during the period that emphasized the development of large-scale, mechanized farms to produce food and raw materials for the growing urban markets.

Farm-Level Impacts

North Shaba farmers who adopted Kasai I received significantly higher returns to land and labor both with and without changes in management practices. A comparison of yields between local varieties and Kasai I under different management levels showed increases of 40-70% for Kasai I on forest and savannah lands (Figure 3.17). Returns to labor were even more impressive. In terms of kg of maize per person/day, the productivity of labor increased from a mean of 5 kg to 8.5 kg with a change in variety only, and up to 16 kg using both Kasai I and improved practices (FAO 1989). These represent increases of between 70 and 300% over traditional seeds and practices.

Changes in Resource Allocations

As a consequence of PNS activities, farmers devoted more land and labor to producing maize. Maize is normally planted on newly cleared land, and most of the incremental area resulted from an expansion of land under cultivation rather than shifts from other crops, although some reduction in cotton area did take place. Although hard evidence is limited, it appears that the additional labor required for expanding maize production and area came primarily from nonfarm activities, including leisure and rural-urban migration. In this sense the experience of North Shaba is unique compared to the other four case-study countries.

Impacts on Consumption

Farmers in North Shaba get about $90-100 per MT for their improved maize, and produce 1 to 5 MT per family. The average is about 2 MT28, which amounts to $200 per year in new cash income. Before maize was introduced they had only trickles of cash income from groundnuts and palm oil. This is a boon in an area where total production, including that consumed on the farm, is estimated to average $100 per capita per year—$500 for a family of five. Maize has become the predominant cash crop. People use the income to improve their houses, and buy meat and fish, chickens, tools, radios, bicycles, and other consumer goods. At the same time there has been an expansion in trading activities associated with more successful farmers who channel a portion of their earnings from maize production into diversifying their income-producing enterprises.

26. The 100,000 MT imported by official channels in 1970 was estimated to be only half of what actually arrived, as there was extensive clandestine importation of maize and flour primarily from South Africa and Rhodesia across the Zambian border.

27. IITA implemented a companion research project focussing on cassava—Projet National Manioc—which was also of this character.

28. The villagers interviewed in Kamwenze, classed as medium or poor by their neighbors (and themselves), claimed to plant about a hectare of maize and to harvest twenty bags (ca. 2 MT). The wealthier farmers had up to 2 ha, with up to 50 bags (5 MT).

Table 3.10. North Shaba Project: Changes in Maize Production and Sales

	Area (000 ha)	Yield (MT/ha)	Production (000 MT)	Maize marketed (000 MT)	Improved seed (000 MT)	Improved road (Km)
1978-79	24.1	1.3	31.5	12.4	23	96
1985-86	33.1	2.9	96.6	47.4	112	1,136

Source: Poulin et al. (1987:3,6).

Gender and Equity Considerations

There were reports that polygamy increased during the life of the project. People stated that men were marrying earlier and more frequently than before, and brideprice levels increased. These changes may be associated with greater wealth and demand for familial labor (Poulin et al. 1987). In addition, the pygmies who provided agricultural labor for southern maize farmers were receiving higher wages by the end of the project. Some pygmies were farming on their own, including producing maize.

Project-Level Impacts

By 1986 the area under maize in North Shaba was 33,154 hectares cultivated by nearly 16,000 households. During the life of the project, commercial activity increased greatly in the major towns and villages throughout the zone. For roadside villages, the major commercial activity occurs during the maize marketing season. Table 3.10 shows increases in the amounts of improved seed used by farmers, maize produced and marketed, and accessibility of improved roads.

Farmers increased production in the early years of the project (1977-81) largely by expanding maize cultivation while accepting project seed. Between 1982 and 1986 the area of maize cultivation remained stable while yields improved as the seed distribution system grew and farmers followed project recommendations for maize cultivation.

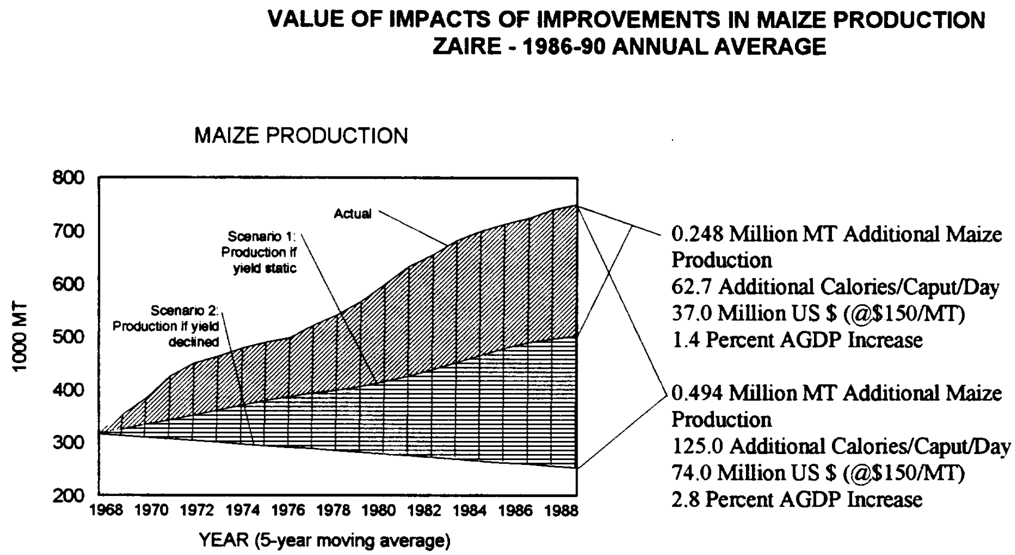
The expansion of maize production has accelerated the clearing of forest lands in North Shaba. Although this land is returned to fallow after 4 years of cultivation and eventually reverts to secondary forest, maize cropping is threatening biodiversity in North Shaba.

National-Level Impacts

Maize production expanded dramatically in other parts of Southern Zaire during the early 1980s, especially in Central and South Shaba and Kasai Oriental Provinces. Extensive use was made of CIMMYT/PNM varieties (e.g., Kasai I, Salongo, and Shaba I) in these areas as of 1985/86 (Hart 1993).

The national impacts of improved technology adoption in maize cultivation are illustrated by comparing actual production trends with what might have happened in the absence of these innovations. As coarse grains other than maize have such a minor role in Zaire, the two “without technological change” scenarios that are utilized here are slightly different: Scenario I keeps maize yields at the 1966-70 average level, while the area planted to maize is allowed to expand as it actually did. Scenario II assumes that yields decline (1% of the 1966-70 average per year) and there is no increase in maize area. The results (Figure 3.18) illustrate the substantial differences that can be traced to technological change. Although the improvements are not as dramatic as those in the other case-study countries, the increases are remarkable considering the adverse conditions in which this progress took place.

Figure 3.18. Zaire Maize Production, with and without Technological Change



The benefits to Zaire from these increases in maize production are demonstrated through the incremental calories, savings in foreign exchange, and improvement in the percent growth of AGDP associated with comparing actual production trends with the two "without" scenarios (Figure 3.18). The increments associated with Scenario II are particularly dramatic. The government's major reason for supporting PNM and PNS was to avoid escalating imports, and in this regard its expectations were realized. The growth in local production has probably contributed to keeping maize prices lower than they would have been, but the markets are so imperfect that this cannot be demonstrated statistically.

The key issue in assessing impacts for Zaire is the source of the resources used to expand maize area. In other countries there is considerable evidence that the expansion in maize area was accommodated by shifting land and labor from other farming enterprises, but this does not appear to have been the case in North Shaba. If most of the labor came from nonagricultural activities and leisure, then it is particularly difficult to estimate the net effects on incomes and productivity. However, if one accepts that farmers are fundamentally rational in their resource allocation decisions, the expansion in maize area in North Shaba, and possibly other parts of the country, does represent positive movements in incomes and labor productivity for large numbers of farm families.

Windows of Creativity

A significant portion of these impacts are associated with the research and development efforts in the southern portion of the country during the 1970s. The government's desire to limit imports of maize was expressed through a decade of support for research, and a willingness to grant PNM management considerable flexibility in efforts to develop suitable innovations. PNM was able to attract and motivate capable Zairian staff. Satisfactory performance was a requirement for continued employment in the project. These conditions, combined with reasonably good continuity in staffing and backstopping from the CIMMYT Maize Program, provided a "window" of opportunity and creativity in a country where adverse conditions have dominated most of the postindependence period.

4. Subregional Perspectives

The character and magnitude of improvements in maize production and productivity vary considerably among the four major subregional groupings of West, East, Central, and Southern Africa (see Table 4.1). This chapter summarizes the impacts from changes in maize production and productivity at the subregional level over the past 25 years. The discussion builds upon the country case study summaries in Chapter 3, while selectively incorporating the experiences of other countries for each subregional grouping.[1]

The focus of the analysis is upon the easily visible changes including

- changes in area, yield, and production of maize;
- shifts in area, primarily from other coarse grains;
- changes in trade and domestic consumption;
- impacts on rate of growth of AGDP.

Collectively, these changes represent the tip of the impact iceberg described in Chapter 1. The methodology is the same as that utilized for the national-level impacts for the country case studies; namely, a series of comparisons between what actually happened with what might have happened in the absence of the technology or with the slower spread of innovations. As one moves to the subregional and SSA levels, the scenarios require increasingly heroic assumptions. Aside from shifts between maize and other commodities in Central Africa, there is no "fine tuning" of the assumptions at the subregional level, although these could be easily accommodated. It was felt that the assumptions should be standardized as much as possible so that they could be easily understood and used for making rough comparisons over time and between regions. Also the results and basic data is presented in a format that facilitates use and comparison in the context of future studies.

As in the discussion of country-level impacts in Chapter 3, consideration is given to what might have happened with more favorable conditions in terms of technology development and transfer, policy contexts, macroeconomic conditions, and rainfall. Optimistic scenarios are, if anything, more speculative than those used for the "with and without technological change" comparisons, but serve to indicate the considerable but diverse potential which SSA and its subregions possess. In addition to the case studies, the assessments draw upon the findings of the CIMMYT study, "Realizing the Potential of Maize in Sub-Saharan Africa" (CIMMYT 1990).[2]

The visible changes reviewed in this chapter tend to distort and generally understate the magnitude and character of impacts. No effort is made to systematically analyze the more obscure consequences of innovations—the portion of the impact iceberg lying below the surface—because, at the subregional level, formal quantification is essentially nonexistent. However, the discussion of the significant differences in impacts among the subregions draws upon the findings of less visible impacts in the country case studies.

1. Impacts for the SSA region as a whole are presented in Chapter 1.

2. In contrast to this study, CIMMYT uses FAO statistics.

Figure 4.1. Map of Africa Showing Major Subregional Groupings

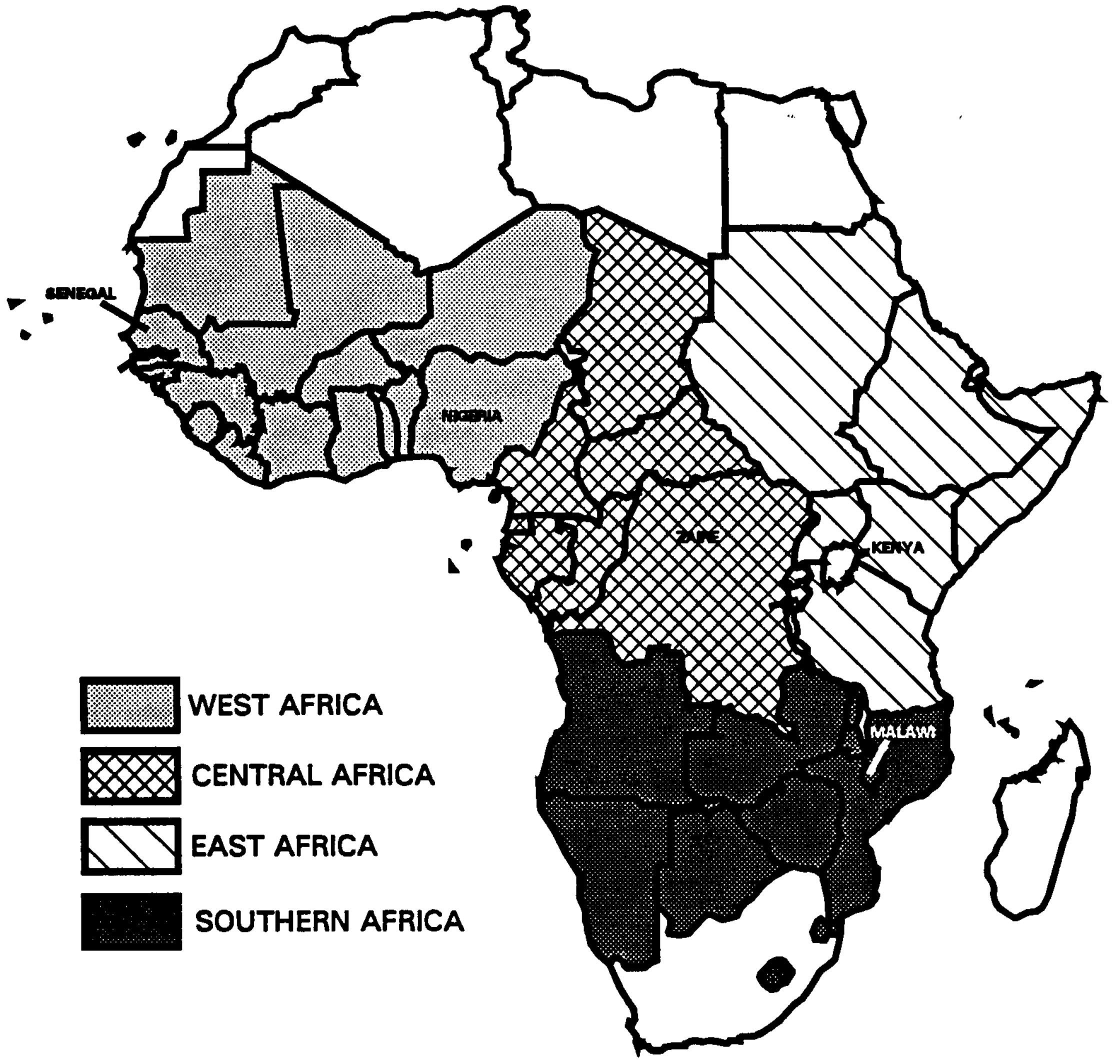


Table 4.1. Subregional Maize and Coarse Grain Production, 1986–90 Average

	Maize (000)		Coarse Grains (000)	
	Area (ha)	Production (mt)	Area (ha)	Production (mt)
West Africa	4,559	4,401	23,582	16,761
Central Africa	1,978	1,617	3,878	3,169
East Africa	5,023	7,477	13,973	13,545
Southern Africa	4,604	5,451	5,813	6,099
Sub-Saharan Africa	16,304	19,086	46,851	39,295

Source: PS&D data, FAS/USDA.

Table 4.2. Average Annual Growth in Maize Area, Yield, and Production, by Region, 1986–1988*

Region	Area	Yield	Production
West Africa	2.40	0.49	2.90
Central Africa	2.84	0.12	2.97
East Africa	1.76	1.98	3.78
Southern Africa	0.96	0.04	1.01
Sub-Saharan Africa	1.8	0.74	2.57

* Percentage of five-year moving average.

Source: PS&D data, FAS/USDA.

East and Southern Africa account for approximately two-thirds of total maize production in SSA (Table 4.1). Although increases in maize yields have been most spectacular in East Africa, annual increases in maize area have been significant in each region (Table 4.2).

WEST AFRICA

Maize is a crop of secondary importance in most West African countries, but has experienced impressive growth over the last 25 years (Table 4.2, Figure 4.2). The expansion has been most dramatic in Nigeria, which accounts for 40% of total maize production in the subregion. As the experiences of Senegal and Nigeria illustrate, a significant portion of this expansion has been at the expense of other coarse grains, particularly sorghum, millets, and groundnuts. However, these commodities continue to dominate the cropping systems of the semiarid portions of the subregion. In the past 30 years, declining rainfall in the northern portions of the subregion has been a major factor in the shifts in cropping patterns that have taken place.

West Africa contains three major agroecological zones, including the Sahel, the Guinea Savannah, and the Humid Forest, each with distinctly different farming systems (CIMMYT 1990). The expansion of maize has been most dramatic in the Guinea Savannah (Smith et al. 1990). This is illustrated by the experiences of Nigeria, which contains all three zones. Progress has also been made in the southern portions of the Sahel (e.g., Senegal, The Gambia, and Mali), and parts of the forest zone (e.g., Ghana and Ivory Coast) where the commodity has traditionally been more important than in the interior (Johnston 1958). Maize has also been used successfully in irrigated cropping systems in the drier portions of the Sahel.

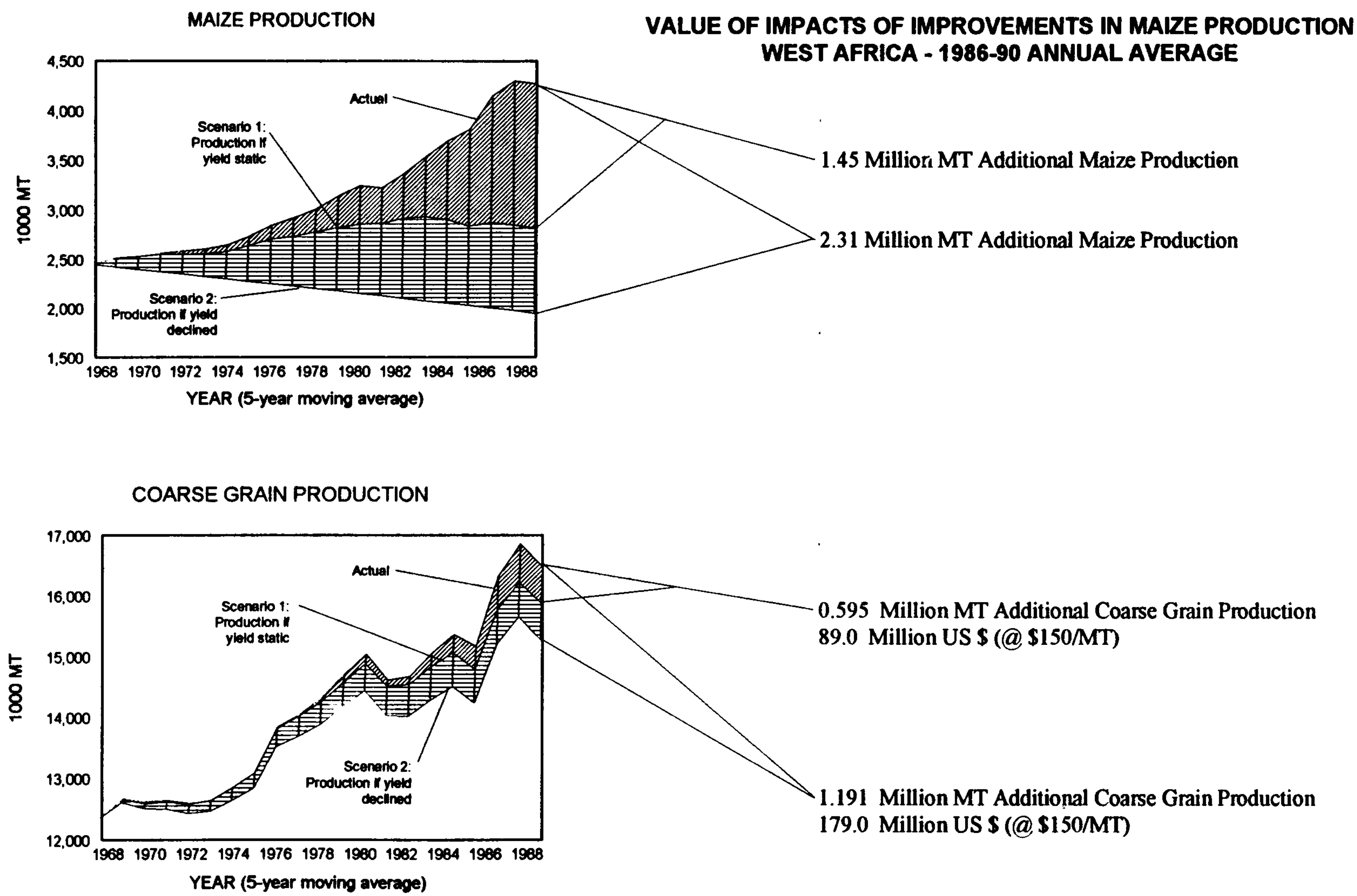
West African maize yields average significantly below those of East and Southern Africa. Maize holds a yield advantage over sorghum and millet, however, particularly on better soils and with well-distributed rainfall (Figure 4.3).[3] As Senegal in particular illustrates, higher yields only partially explain the attraction of maize for farmers. Returns to labor and convenience in meeting food and cash requirements during the early harvest period are also major factors.

Subregional Impacts

Compared with the two "without" scenarios, technological change has accounted for average annual production increases of between 1.5

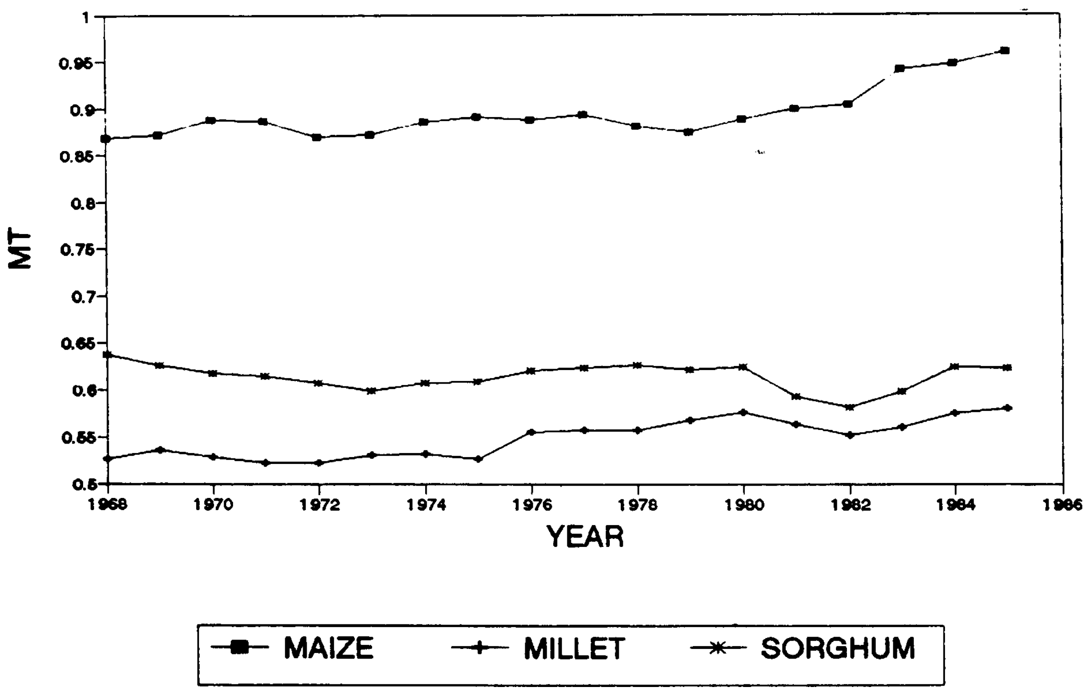
3. Figure 4.3 probably overstates the yield gap, since sorghums and particularly millets tend to be grown under less favorable conditions (soils and moisture) than maize.

Figure 4.2. West Africa Maize and Total Coarse Grain Production, with and without Technological Change



Source: See Annex D.

Figure 4.3. West Africa Coarse Grain Yields



Source: See Annex D.

and 2.3 million MT of maize between 1986 and 1990, and a net improvement of between 600,000 and 1.2 million MT in the annual production of coarse grains (Figure 4.2). A significant portion of the additional calories from increased maize production comes from the green maize eaten during the early harvest period. Consumed in this form, maize is a convenience food that reduces processing and food preparation demands upon women. This is one example of how national statistics considerably understate the impact or "value" of the added production from the perspectives of farm families.

In terms of food security, West Africa has moved from self-sufficiency to increasing dependence on imports and food aid since the 1960s. Progress in maize production has not been sufficient to offset this trend, but the situation might have been worse without the expansion of maize. The additional coarse grain production is equivalent to between US$89 million and $179 million annually of cereals that might otherwise have had to be imported.

Optimistic Scenarios

A major factor affecting change in the semiarid portions of the West African region has been the decline in rainfall, which has simultaneously encouraged a shift to shorter-cycle cereals and the expansion in animal traction. Although total area under cultivation has declined in many instances, maize has expanded, in some cases dramatically, despite decreasing resources devoted to agriculture. It is not particularly useful to speculate on what might have happened with more rain except to provide insights into the reasons for the changes that took place. If one views the popularity of maize primarily as an adjustment to adversity, then much less maize would have been produced in West Africa had rainfall not decreased.

This argument is not tenable from at least four perspectives. First, farmers planted maize on the better soils of the inner fields, replacing sorghum, millet, and cash crops. The primary reason for this substitution is the higher returns to land and labor that farmers realized from maize compared to other commodities. In all likelihood, more rainfall would only have further widened this productivity gap.

Second, a major constraint to maize production was its minor importance in farming systems and the West African diet. In the semiarid regions, maize transactions in rural markets were few and seasonal in nature. Although general ecological conditions favored maize production, farmers regarded the crop as something produced on the side largely for seasonal home consumption, rather than a serious prospect to replace other commodities as a source of food and cash.

Research and development efforts in Senegal, Mali, The Gambia, and Nigeria as well as other countries were instrumental in overcoming this attitudinal "block" or prejudice that many farmers and consumers had against maize. The special projects in particular were instrumental in dealing with this "chicken and egg" problem by encouraging the expansion of maize production through promotion, subsidized inputs and, in some instances, by assistance in marketing itself (or at least access to markets through improvements in roads). The availability of innovations, especially seed and fertilizer, served to reinforce these efforts.

Third, the expansion of maize tended to fuel itself by increasing the volume of transactions in the markets and by the willingness of populations to substitute maize for other staples in a range of preparations. Rainfall does not emerge as a critical factor in this shift.

Fourth, maize production also expanded in countries such as Ghana and the Ivory Coast where the commodity was already well established and rainfall is generally adequate to support one or even two crops a year. While lower rainfall may have encouraged a shift from root crops to maize in the northern portions of these countries, the major factors appear to be research and development efforts as well as the general policy contexts rather than the weather.

The experience in Ghana illustrates the effects of sustained research and development efforts for maize spanning more than a decade. The Ghana Grains Development Project (GGDP) was launched in 1979 as a collaborative effort involving the Crops Research Institute, the Ministry of Agriculture, the Grains and Legumes Development Board, and CIMMYT, and has received consistent support from Canada (CIDA) (GGDP 1991). This impressive set of internal and external linkages and support arrangements was complemented by farmer experience with maize, especially in the central and southern portions of the country where the commodity is a major staple food. A central theme of GGDP is interactions among researchers, farmers, and extension staff in the context of on-farm trials throughout the country. Sets of recommended practices for different ecological zones covering variety, fertilization, and plant stand management received widespread exposure via various extension projects, including Sassakawa-Global 2000, which has been actively promoting improved packages for maize by demonstration plots and supervised credit since 1986.

The experience of GGDP illustrates the potential as well as the limitations of the new technologies. An adoption study conducted in 1990 found that nearly half the area surveyed, covering all three major zones in the country, was planted to improved varieties (GGDP 1991). But the recommendations for fertilizer and plant stand management were utilized in only one-third of the survey area. Use of improved germplasm is difficult to estimate precisely since only OPVs are involved, but farmers continued to use local varieties, particularly in the maize-dominant areas (transitional and forest zones) and for intercropping. Farmers generally perceived local varieties as having superior storage and processing characteristics, although this was less important in the northern savannah zone where maize is a secondary commodity. Seed supplies also constituted a problem.

Fertilizer use was sensitive to price and credit; as subsidies (via overvalued exchange rates) and loans from Sassakawa-Global 2000 were reduced, fertilizer purchases decreased sharply. In addition, farmers appeared to prefer traditional methods over line planting as a means of raising plant populations to optimal yield levels. Although GGDP has made considerable progress, especially in relation to earlier efforts (e.g., the Focus and Concentrate Program supported by USAID in the 1970s), there is still much more to be done in adjusting technologies to the requirements of local farmers and consumers. Recommendations on crop management practices in particular require further adjustment, and the implications of intercropping, labor use, and soil fertility management must be taken into account in order to improve their acceptability.[4]

The status of maize as a crop of secondary importance in most West African countries effectively insulated it from anything more than passing attention by officials concerned with pricing and marketing policies. The policy factors that might have been more favorable to maize production include (i) exchange rates; (ii) food imports and aid; and (iii) government involvement in input delivery.

Exchange rate policies resulting in overvalued local currencies cut both ways by making it more difficult to compete with imports while reducing the cost of fertilizer. In general, maize producers were insulated on both fronts by the fact that little maize was imported, except episodically from neighboring countries, and fertilizer prices were set by government policies, often involving an additional subsidy element. This was clearly the case in Ghana to the point where fertilizer became almost free (Eadmeades et al. 1991).

Policies on food imports and aid were of some importance in Senegal since the government allowed cheap imports of maize, especially for poultry feed, which tended to discourage domestic production in this market. At the other extreme, maize production received a major boost from the ban on cereal imports in Nigeria in the late 1980s.

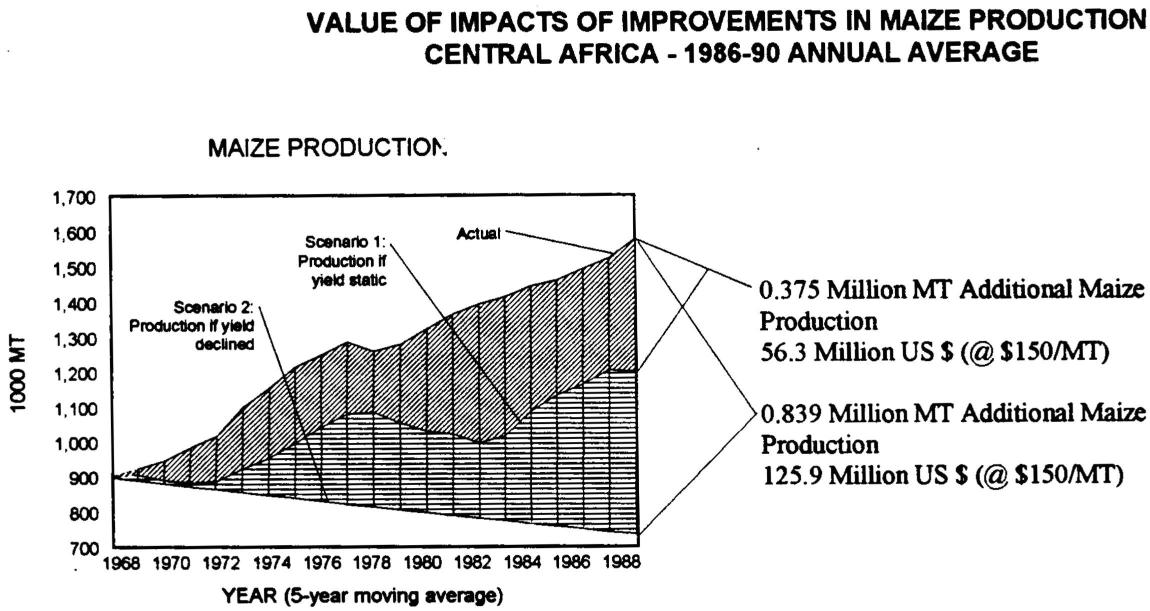
Maize development efforts could have benefitted from greater research efforts, particularly by the national research services of the region, but as a commodity of secondary importance it is remarkable that maize received as much attention as it did. The Semi-Arid Food Grain Research and Development (SAFGRAD) project has played a significant role in the identification and dissemination of improved maize varieties among member countries in West Africa since its inception in 1977 (Sanders et al. 1994). The supply of and access to inputs, especially improved seed and fertilizer, emerges as the most important factor limiting the expansion of maize production in the region. The supply and pricing were controlled by governments in many instances and, in spite of subsidies, farmers were frequently unable to obtain the quantities they needed. The absence of a significant commercial farming sector also limited the feasibility of hybrid seed production outside of a few countries, notably Nigeria. Improvements in farmer access to new varieties and fertilizer could have dramatically fueled the expansion that took place and may still do so in the future.

CENTRAL AFRICA

Maize production in the Central African subregion has nearly doubled in the past quarter century, despite the fact that large areas are not particularly well suited to the production of the crop. Among the subregional groupings, maize is least important in this portion of SSA, accounting for 10% of total crop area but 55% of coarse grain production (Table 4.1). The high

4. The project has, in fact, been devoting increasing attention to maize-cassava intercropping in recent years (GGDP 1991).

Figure 4.4. Central Africa Maize Production, with and without Technological Change



Source: See Annex D.

rainfall and low solar energy that characterize much of the subregion generally do not favor maize compared to root crops and perennials. Further, serious research and development efforts to date have been confined largely to two countries, Zaire and Cameroon. Relatively little has been attempted in the other countries, some of which, such as Chad and Central African Republic, include large areas that are well suited to maize production. In short, the subregion has considerable potential to benefit from the initial set of varietal changes that have been successfully introduced throughout other areas of SSA.

The Zaire case study, focusing on North Shaba Province, illustrates the progress that can be made, even in the face of a formidable array of constraints. Conditions have been considerably more favorable in Cameroon, and it is understood that the MSU ROR study for the country will report recent progress resulting from collaborative research and development efforts involving government agencies and IITA.

Given the variety of conditions found in this part of SSA, it is particularly difficult to find meaningful generalizations on impacts at the subregional level. It is clear, however, that Central Africa has shared in the expansion in maize production that has taken place, and offers considerable scope for future progress.

Subregional Impacts

The assumptions for the "actual" versus "without innovations" comparisons differ for Central Africa since it was felt there was no basis to suggest direct competition for resources between maize and other coarse grains. The expansion of maize in Zaire has occurred largely as a result of bringing new areas into cultivation, and evidence is very limited for other countries (Figure 4.4). It is probable that area shifts are involved, but for purposes of the present analysis it was not felt that additional "fine tuning" of assumptions would dramatically change the picture that emerges.

Scenario I holds the yields at the 1966–70 average level as with the other subregions; however, the area expansion for maize is identical to what actually happened. The experience of North Shaba in Zaire suggests that new areas were brought into production largely in response to new roads and generally improved access to markets, rather than as a consequence of innovations. This assumption probably understates the impacts of innovations but, on the other hand, no account is taken of a shift from other crops to maize that might have taken place as a result of maize technology. Both these elements—namely, the stimulus of innovations and the substitution of maize for other enterprises (not limited to crop production)—should be taken into account in determining net impact, but there is insufficient information to make easily defendable assumptions in either case.

Scenario II assumes that maize yields decline and that the area planted to maize remains static. Unchanging areas of land planted to maize in the face of declining yields infers that there are no shifts to other commodities. This probably overstates the gap but, together with Scenario I, indicates a range within which the results of virtually all other possible scenarios can be found.

Comparison of the actual trends in production with the two scenarios shows an improvement in maize production ranging from 375,000 MT to 839,000 MT annually on average for the period 1986–90. This is equivalent to a reduction of maize imports of between US$56 and $126 million per year.

Agricultural research has led to the development of disease- and pest-resistant maize varieties that have contributed towards the overall food security of the subregion. Increased maize production in Shaba has reduced food expenditures associated with the importation of supplies for the urban centers of southern Zaire.

Optimistic Scenarios

The improvements in maize production that have been achieved in Central Africa are impressive considering the minor place it occupied in the farming systems. The Zaire case study shows that the same factors that helped to increase the role of maize in North Shaba could also improve maize production levels throughout the subregion. These factors include (i) improvement in the road network which, in North Shaba, allowed farmers to follow the roads and clear new land on which maize was grown; (ii) the mobility of the population; (iii) improvements in input distribution; and (iv) increased geographical scope of maize research and development. Political instability and civil strife have inhibited the improvement of all these factors throughout the subregion.

The Zaire case study shows that market opportunities are powerful incentives for farmers in the subregion. With improved access to markets and ability to purchase inputs, it is likely that maize production would be even greater throughout Central Africa. Farmers respond quickly to market opportunities when profitable linkages are established between production zones and major consuming centers for maize in towns and cities.

Government policies in both Zaire and its neighbor, Congo (Brazzaville), gave priority attention to large-scale state farms, which was reflected in the character of research and development efforts during most of the postindependence period. In the Congo, little attention was given to traditional dominant root crop staples, and even less to maize (Phillips and Doulou 1991). Congo illustrates the "without technological change" scenario. Yields have remained low and the proportion of area devoted to maize has not changed significantly in the past 20 years. More attention to improving smallholders' production might have improved the situation, although possibly not as dramatically as in southern Zaire or northern Cameroon, which provide more suitable conditions for maize production.

Maize research and development efforts for smallholders have received considerable attention in Cameroon since the late 1970s through the USAID-supported National Cereals Research and Extension (NCRE) Project. IITA participated in the project and was the source of many of the technologies, particularly improved germplasm. A Testing and Liaison Unit was created to conduct on-farm trials and ensure transmission of information between farmers, extension workers, and researchers. Special attention was given to the use of minikits to popularize improved varieties and facilitate farmer feedback. Improved varieties developed by IITA have been adopted by an increasing number of farmers, especially in the northern parts of the country with ecological conditions similar to those in the Guinea Savannah zone of Nigeria.[5]

The key issue in considering more optimistic scenarios for Central Africa is the labor required for expanding maize production and where it would come from. Arable land is plentiful compared to the rest of SSA, but it seems unlikely that further expansion could take place without the diversion of labor from other enterprises. It is possible that road development, coupled with strengthened extension activities, would encourage shifts from other commodities.

For the residents of these areas, however, the substitution process is likely to be influenced by the pace of changing tastes for staple foods as well as the availability of markets. Maize might be easily substituted for cotton and other cash crops as defined by relative prices and returns to resources, but farm families may be less enthusiastic about rapidly changing their own dietary patterns from root crops to maize, even where there is a clear productivity gain.

Another possibility is that improvements in roads and markets would be accompanied by migration from land-scarce areas such as Rwanda and Burundi. Such migrations are a major feature of agricultural change in West Africa, but less so elsewhere except as a direct consequence of civil unrest. Countries in the area, especially Zaire, already contain substantial numbers of refugees from other subregions. There are considerable socioeconomic and political tensions in the recipient countries associated with these movements, and there is question whether additional migration would be welcomed. Further, the environmental consequences of such population movements, in the form of accelerated clearing of forest lands, would be largely negative.

EAST AFRICA

In contrast to West and Central Africa, maize is an important food source throughout East Africa, and is the dominant staple in both Kenya and Tanzania. The position of maize in farming systems throughout the subregion has strengthened steadily in the past 50 years and shows no sign of abating (CIMMYT 1990). Such comprehensive growth is remarkable in view of the diverse agroecological conditions, population densities, and farming systems that characterize the subregion.

Maize has received considerable attention by research and development throughout the subregion. Although Kenya is the most well-known and frequently cited experience, serious efforts have been made in other countries. These have resulted in progress, often in the face of adversity. Kenyan success can be attributed to a combination of favorable political, environmental, and policy factors: the initial core clientele were large-scale commercial producers farming high-potential land; they profoundly influenced the pace and direction of research and extension as well as the general policy context. Smallholders subsequently followed their more fortunate counterparts onto the policy agenda. In contrast, civil strife and unfavorable macroeconomic contexts have been dominant features of virtually all the other countries in the subregion during this period. When peace is

5. Impacts from maize, and development in Cameroon are part of the ROR studies being conducted by MSU.

restored and policies adjusted, which is the trend in at least some countries, there are considerable areas which could benefit from the advances for maize which have already been made.

Subregional Impacts

Maize production has more than doubled in East Africa in the past 25 years from an annual average of 3.6 million MT (1966–70) to 7.5 million MT (1986–90) (Figure 4.5). The maize portion of total coarse grain production has also increased from 36% to 50% during the same period. Kenya has led the way in the development, release, and adoption of hybrid and composite maize varieties. Hybrid maize combined with fertilizer has allowed farmers to double yields. Short-duration composite varieties have encouraged the expansion of maize into the drier, semiarid areas at the expense of bush and grazing land.

The expansion of maize production in the subregion is attributable both to a 50% increase in aggregate yields (Figure 4.6) and to increased area planted with maize. CIMMYT estimates that maize production in the subregion grew by an average of 2.7% per annum from 1961 to 1988, of which 1.6% is accounted for by yield improvement and 1.1.% by area expansion. This increase in average yields is impressive, especially when compared to that of coarse grains which currently yield only half that of maize. However, the yield difference also reflects the fact that maize has displaced other coarse grains on better land, leaving sorghum and millet to the low-potential, driest areas which cannot easily support a maize crop.

Improved maize production, through increases in both yields and area, has had important subregional impacts. If maize yields had remained static, by the latter half of the 1980s the cost of importing coarse grain to substitute for this increment in production would have reached an annual sum of between US$339 and $530 million. Maize technologies have improved the incomes of many subsistence farmers in the subregion, either through increased yields and profits from the sale of surpluses or by lower expenditures on family food.

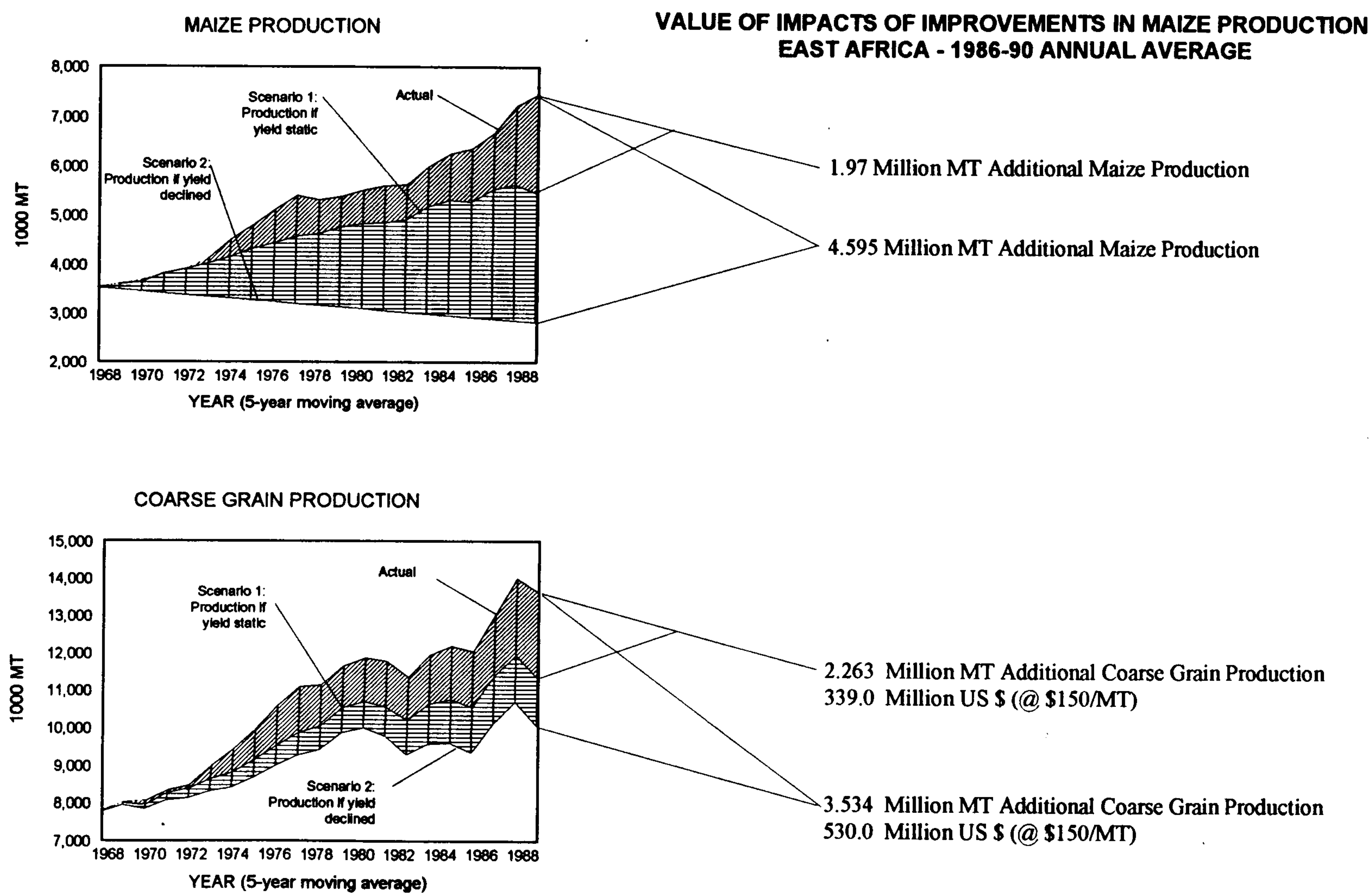
In Kenya these improvements have had a significant impact on food security, enabling the country to remain self-sufficient through the 1980s in the face of a 4% rate of population growth. In the past three decades the country has only had to import grain in 3 years of severe drought. Aggregate subregional increases in maize production obscure the impacts of war and drought-induced devastation to the agricultural economies of many of the nations in the subregion. Sudan, Ethiopia, and Somalia remain heavily dependent on food aid, particularly to feed refugee populations. Despite these negatives, there is both macro- and microlevel evidence of improved maize yields or expansion in maize area throughout East Africa.

Optimistic Scenarios

War and adverse politics have caused disruptions to both agricultural institutional infrastructure and smallholder farming systems. If these negative conditions were eliminated it is possible that variants of the improved maize technology currently available would enable the subregion's nations to produce adequate food supplies, including reserves for poor years. The capacity to export is a possibility, although it is not clear that production costs could be reduced enough to make this a reality. Although technical challenges remain to be addressed, many of the problems of maize in Africa appear institutional and financial rather than purely technical (CIMMYT 1990). In order to realize the potential of maize in Africa, technical, institutional, and financial obstacles have to be overcome simultaneously. Kenya is an example of what can be achieved, and there is both macro- and microlevel evidence in other East African nations that maize production would improve significantly if these obstacles were removed.

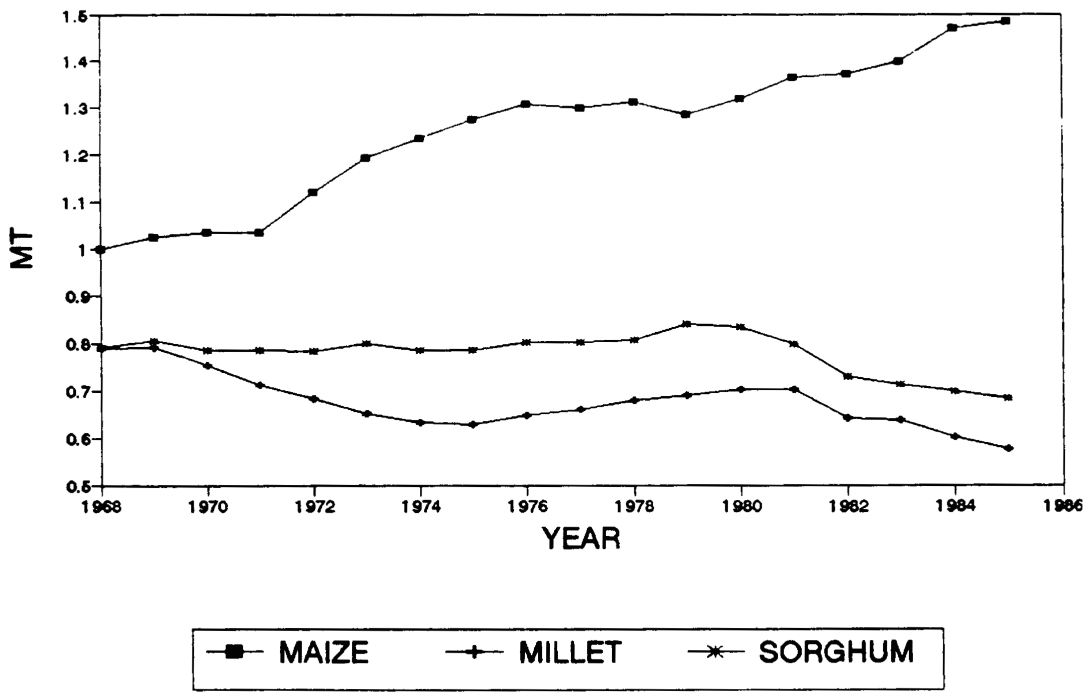
Somalia is an example of the success of government policy measures in encouraging

Figure 4.5. East Africa Maize and Total Coarse Grain Production, with and without Technological Change



Source: See Annex D.

Figure 4.6. East Africa Coarse Grain Yields



Source: See Annex D.

maize production. The program of structural reform during the 1980s witnessed an impressive growth in maize output. At the national level, the growth in the area planted to maize leapt from decline in the 1960s and near stagnation in the 1970s, to an annual increase of 5% from 1981 to 1990, more than twice the rate of other countries in the region. Yields exhibited a similar trend and overall production soared, increasing by 10% each year in the 1980s (CIMMYT 1990; 1992). Microlevel evidence shows that farmers in the Shabelle River Valley responded positively to the structural adjustment measures taken in the 1980s. This response, however, was mostly due to area expansion rather than increases in productivity. Although a maize technology package had been developed using the "Somtux" variety, which offered to double yields, institutional constraints and lack of inputs prevented these farmers from using it (Wehelie 1989).

Ethiopia illustrates how research efforts can make progress even in the face of considerable difficulties. At the national level, average maize yields have increased continuously since 1962, and production has grown since 1973 despite civil war (CIMMYT 1990). The Institute of Agricultural Research based in Addis Ababa has successfully developed early-maturing maize varieties using genetic material similar to that at Katumani in Kenya (Negassa, Mwangi, and Beyene 1992). The Institute attributes this progress to on-farm research. However, poor research-extension linkages and civil war have slowed the spread of this success from Bako, where the early-maturing variety "Guto" was developed.

The recent experience of maize research in Uganda shows what progress can be made when negative conditions are removed such as the civil war that raged in that country from 1979 to the late 1980s.[6] Unlike much of Eastern Africa,

6. The discussion on Uganda was provided by Laker-Ojok (1992).

maize is not the major staple in Uganda; it is a smallholder crop produced with no improved inputs and accounts for less than 8% of total area under cultivation. Yields are restricted by nitrogen and phosphorus deficiencies in the soil and by the prevalence of maize streak virus (MSV), which can reduce yields by up to 80%. During the 1970s, as marketing systems for cotton collapsed, maize began to be produced as an alternative cash crop. This coincided with increasing urbanization and falling incomes. As a fast-cooking, easily storable, low-cost staple, maize meal met an important demand for urban and institutional consumption. Overall, probably 60% of current maize produced is sold on the market.

Prior to 1991, Uganda had released only three improved OPVs, of which only one—Kawanda Composite A—was ever produced in significant quantities. This tall, late-maturing variety degenerated due to lack of maintenance breeding and seed production during the civil unrest. Complaints focused on its high susceptibility to MSV and blight diseases, excessive plant and cob height, and severe lodging. In 1989, streak-resistant material from IITA was crossed with a shorter-season variety. The result is a medium-maturity variety that is streak resistant and moderately resistant to Northern Corn Blight. It exhibits a 20–35% yield improvement over traditional varieties even under low-input, farmers' conditions. The variety was released in 1991 as "Longe 1" and is undergoing multiplication. A recent study indicates that the projected rate of return to the investment in maize research since 1985 is 27–35% by the year 2006.

In Rwanda and Burundi, yields, area, and maize production have increased consistently since 1962, although the upward trends began to level off in the last decade (CIMMYT 1990). As in Ethiopia, a farming systems approach has made progress, but with contrasting results. Farming systems trials in both Rwanda and Burundi have shown that adaptation of Kenyan germplasm is not always appropriate (Zeigler 1986; Haugerud and Collinson 1990). Trials of Kitale synthetics in local bean intercrops have shown that they offer farmers no biological or economic advantage, while substantially increasing risk (Zeigler 1986). The farming systems approach has enabled agricultural researchers in Rwanda and Burundi to develop selection and evaluation methods that should ensure future releases will be more compatible with farmers' needs.

In Tanzania, maize yields, area, and per capita production have been increasingly consistent over the past three decades (CIMMYT 1990). This improvement in the face of economic difficulties is traceable in part to the spread of improved varieties, some of which come from Kenya or were developed by the national system in collaboration with CIMMYT. Early-maturing varieties such as "Kito" have improved on the storage characteristics of Kenyan Katumani varieties.

Research and development efforts in Kenya and other countries in East Africa illustrate the considerable potential that exists. With improved conditions throughout the subregion, similar efforts could have been mounted using the same basic technologies but adapted to local requirements, as in Bako, Ethiopia. However, Blackie (1989) envisages a need to fundamentally reorient maize research to the needs of low-resource farmers. Nevertheless, both adaption to local environments and reorientation to the needs of low-resource farmers will require improvement in FSR/E capacity beyond what has been realized so far in most of the subregion.

SOUTHERN AFRICA

The Southern Africa subregion is unequivocally the maize-dominant part of sub-Saharan Africa. Maize accounts for 76% and 86% of coarse grain area and production, respectively. It is the major source of calories for all the countries of the region with the exceptions of Botswana, Namibia, and Angola. The importance of maize reflects the favorable agroecological conditions for the crop as well as long-standing research and development efforts. Variations in rainfall, however, particularly in the drier areas, have produced major year-to-year swings in yields and production. Drought conditions throughout major portions of the subregion, including South Africa in 1991/92, produced one of the poorest maize crops on record and necessitated large imports from abroad.

Settlers and large-scale commercial producers have been major factors in national production in some countries, particularly in Zimbabwe and Zambia. These groups have supported the expansion of input companies, including the Seed Cooperative in Zimbabwe, and influenced the character of policies and research and development efforts for maize generally. In recent years, however, attention has turned increasingly to serving the needs of small, low-resource farmers, especially in Zimbabwe and Malawi.

Geographically, the subregion includes South Africa, which has been a major exporter of maize as a well as an important source of technologies. Commercial agricultural activities, mining, and industrial development have greatly increased the number of people who rely primarily on the market for their food needs. Markets are regulated in most countries, and the price of maize has figured prominently in macroeconomic policies, most notably in Zambia. In general, governments have made an effort to keep domestic maize prices low given its importance as a wage good for the urban and mining sectors. This has adversely affected interest in production, particularly among commercial producers in Zimbabwe and Zambia. In some countries, however, research advances, especially hybrids using germplasm from South Africa and Latin America, have been broadly disseminated among small and large farmers alike. These innovations have helped to improve productivity and reduce the adverse effects of declining real prices. Most importantly, the hybrids have contributed to the food security of large numbers of households.

Political conditions have profoundly affected the course of maize and economic development efforts generally between countries. Angola and Mozambique both have considerable agricultural potential, but have been in the grip of civil wars for more than a decade. Zimbabwe maize production experienced a major surge following independence and the termination of hostilities in 1980, with virtually all the growth taking place in the communal areas (Rohrbach, 1988). Zambia has experienced serious problems traceable to contradictory and nonsustainable policies in which maize prices played a central role and eventually contributed to a change in the government.

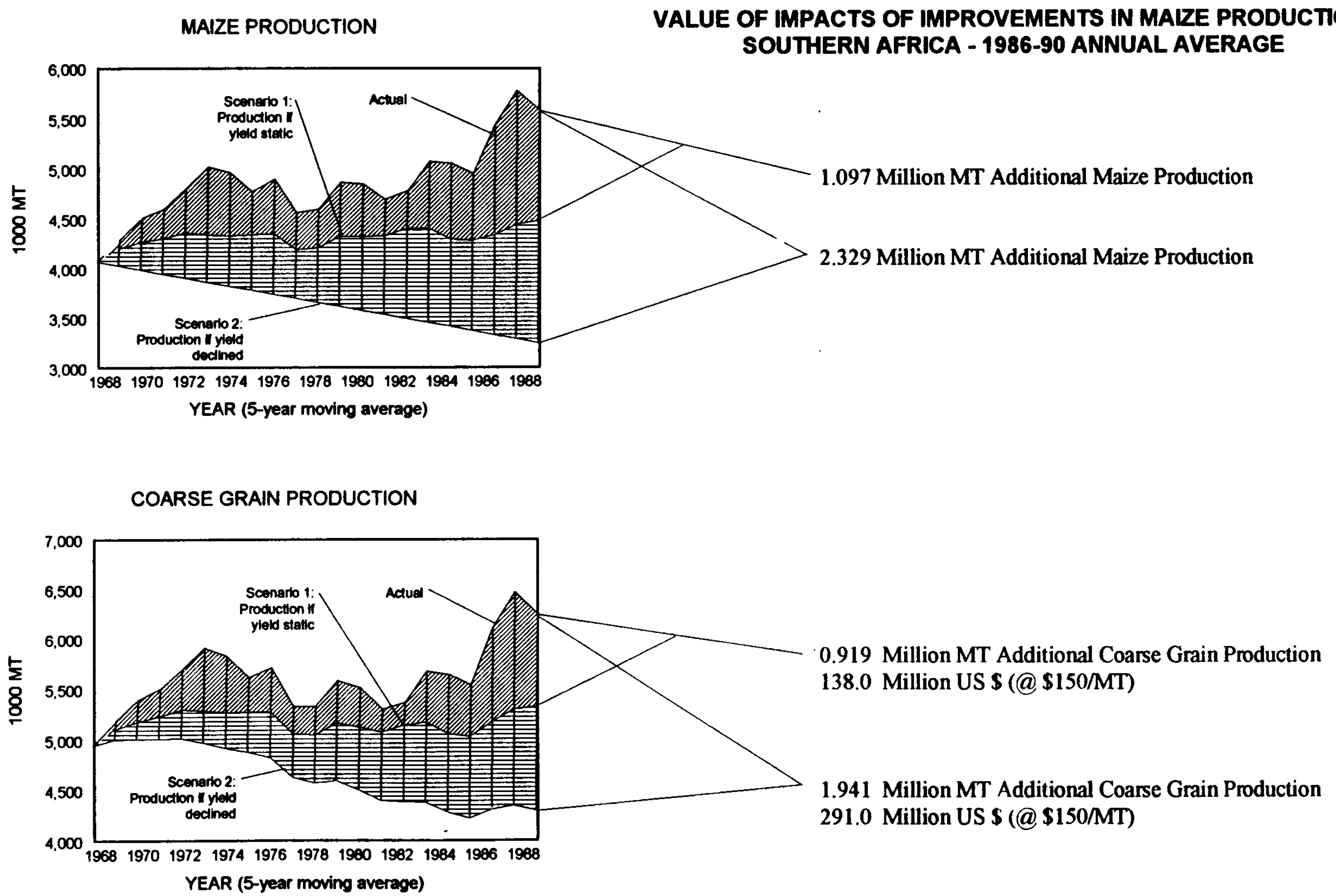
Subregional Impacts

Maize production in Southern Africa has increased from 4.1 million MT (average annual production) in the late 1960s to 5.5 million MT in the late 1980s (Figure 4.7). As in East Africa, this represents an increasing proportion of coarse grain production as maize has advanced partially at the expense of sorghum and millet.

Although maize yields are significantly higher than those of sorghum or millet, average yields have not exhibited any clear trend over the past two decades (Figure 4.8). Consequently, the visible impacts from the expanding use of improved maize technology in the subregion are not impressive, despite the fact that major changes have taken place, especially in Zimbabwe. At the aggregated subregional level the increases in maize production are primarily the result of expansions in area.

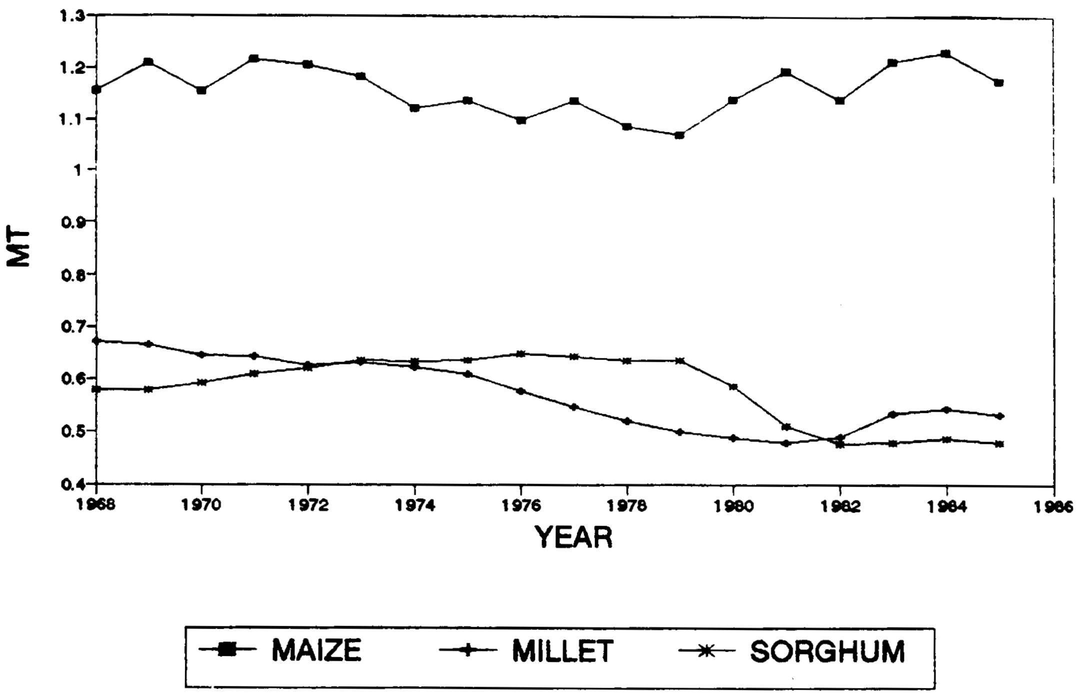
The use of aggregate data is perhaps least satisfactory for Southern Africa compared to the other subregions. For Malawi, both yields and area have changed slowly in the past 15 years. Angola and Mozambique have been plagued by civil wars and should perhaps be placed in a separate category. Yields went down in Zimbabwe as maize area expanded into the communal areas and declined in the higher-

Figure 4.7. Southern Africa Maize and Total Coarse Grain Production, with and without Technological Change



Source: See Annex D.

Figure 4.8. Southern Africa Coarse Grain Yields



Source: See Annex D.

potential areas following independence and policy changes. In Zambia, yields increased, possibly in response to highly subsidized inputs, thus reversing the yield declines between 1960 and the mid-1970s.

The two scenarios indicate the possible trends in maize and total coarse grain production in the absence of technological change (Figure 4.7). There is little difference between Scenario I (static yield) and the actual trend prior to the 1980s, when maize yields increased moderately while sorghum yields in particular drifted downward. The gap is significant for Scenario II (declining yield and area), which indicates the possible combined effects that pests, drought, and declining soil fertility might have had on coarse grain production in the subregion in the absence of innovations. The additional annual production of coarse grains associated with improved technologies ranges from 0.9 million MT (Scenario I) to 1.9 million MT (Scenario II) (1986–90 average). The cost of importing an equivalent amount of maize would have been between US$138 and $291 million per year.

Over the last 25 years, regional food security has been at the mercy of the vagaries of war, adverse policies, and drought. To conclude that food security has not improved because of limited and fluctuating improvements in maize production is to overlook the potentially worse disaster resulting from a decline in maize yields as illustrated by Scenario II. In the Malawi case study, the link between national and household food security and maize innovations is perhaps the most evident because of the greater importance of maize in the diet and the economy. There is evidence that declining national and household food security has been partially offset by recent increases in the use of hybrids.

New technologies for maize have not been adopted to the extent of leading to significant yield increases when measured at the subregional level. In some nations of the subregion, extension and adoption have been prevented by war, and increases in production will be a peace dividend. In Malawi, nonresearch factors such as seed production, input distribution, and output marketing, together with static extension messages, have constrained the diffusion of innovations. Debate over the appropriateness of hybrids versus OPVs for small farmers, and the search for suitable germplasm to use in adapting hybrids to local requirements, have also adversely affected research output.

Maize production in both Zimbabwe and Zambia has been characterized by a dichotomy between large-scale and small-scale maize production. Partly for this reason, grain type for the most part has not been the research issue in these countries as it has been in Malawi (Heisey 1992).

In Zimbabwe, there has been a major shift in maize production from the commercial to the communal sector in recent years. Some factors crucial to this shift (e.g., seed marketing in smaller packages) began even before the end of the liberation war, but accelerated when the war ended. Yields in both the commercial and communal sectors have *increased* over most of the period covered by the MARIA study (Rohrbach 1988). Yield increases in communal areas were related to the spread of maize varieties such as R201 and R215 with traits such as early maturity, which made them more suitable for areas with lower rainfall and sandier soils. However, the shift from commercial to communal maize production in Zimbabwe has meant that aggregate yield has *declined* over the period in question. Furthermore, there are some indications that yield increases in both commercial and communal sectors have slowed in recent years. Finally, even before the current drought, weather-related variability in maize yields has probably been greater in Zimbabwe than in any of the other major maize-producing countries in the region (Heisey 1992).

Zambia, which urbanized rapidly in the last 30 years, also concentrated much of its initial research efforts on large-scale maize production by commercial and settler farmers, and depended on them for most of its maize output. Both maize producers and maize consumers were subsidized considerably and, as the Zambian economy weakened from the early 1970s onward, fluctuations in policy had major impacts on maize production. Large-scale maize production was based on the Zimbabwe hybrid SR52 and its Zambianized successor, MM752. Another notable policy was the government's efforts to expand maize production into areas where maize had not been the major starchy staple. At the beginning of the 1980s, the research system released several hybrids, notably MM603 and MM604, with good performance and earlier maturity. Coupled with favorable, though fluctuating prices, the release of these hybrids led to the dissemination of hybrid technology to a large proportion of small-scale producers. With recent changes in policy, it is doubtful that adoption and yield trends can yet be adequately summarized. There is some evidence that policy may be reorientating itself towards large-scale maize producers.

Optimistic Scenarios

Of all the subregions, Southern Africa stands to benefit most dramatically from peace and policy reform, including the successful transition to majority rule in South Africa. If conflicts and constraining policies were eliminated, there is little question that the region would be an exporter of coarse grains and/or be able to divert considerable resources (land, labor, and capital) from maize production to other activities. The experience of Zimbabwe following independence illustrates what might still happen in other countries with large areas suitable for maize production, especially Zambia, Angola, and Mozambique. The dense population of Malawi, together with recent advances in hybrids and soil fertility management, make this country particularly well positioned to meet domestic needs and possibly free some resources for other activities.

Confrontation with South Africa has inflicted major costs on the countries of the subregion. It is difficult to imagine what might have happened in the absence of an apartheid regime and closer economic links with the Republic. However, a peaceful transition could still provide the basis for major progress in the subregion through the expanding demand of the urban sector, improved access to inputs and technologies, and greater support for research and extension efforts. In short, the optimistic scenarios for Southern Africa illustrate the considerable potential that exists for dramatic advances in the near term, thus setting the subregion in a class by itself compared to the rest of SSA.

SUMMARY

Major impacts have taken place throughout SSA, but especially in East Africa. Although the area under maize expanded in that subregion and shifts of resources from other enterprises took place, the impacts are traceable primarily to increased use of innovations on existing maize fields. In many instances the impacts on maize production were obscured or invisible in nature, particularly in the Southern African subregion. The innovations, particularly improved seeds and fertility management, enabled farmers to produce considerably more maize for the same inputs of land and labor, or at least maintain productivity levels in the face of declining conditions caused by drought, pests, and lower soil fertility. Generally, the new technologies were easily accommodated in the contexts of the existing farming systems.

In contrast, the impacts in West and Central Africa were traceable to more complex patterns of resource reallocation by farmers where maize production expanded at the expense of other activities. The area devoted to maize in these two regions has more than doubled since the mid-1960s. Thus, while West and Central Africa account for lesser shares of total production increases for the SSA region, they represent part of profound adjustments in the farming systems of those subregions which are still in progress.

The comparison of actual trends in each of the subregions with the two “without technological change” scenarios illustrates a range of possible visible impacts from the adoption of innovations, and underlines the diversity found in the SSA region. While it is difficult to make generalizations based on the sample of case studies or even a larger selection of countries, maize innovations have made substantial contributions to food security and the reduction in food imports throughout the SSA region.

5. Conclusions

The conclusions of the MARIA study build upon the findings of the case studies. These findings illustrate the character and magnitude of the impacts associated with efforts to improve maize production throughout the region. Frequently, data are lacking, particularly in a format that lends itself to systematically tracking the consequences of innovation adoption for maize in terms of improvements in productivity, adjustments in resource allocations, and changes in consumption patterns. Further, it is difficult and perhaps less than productive to attempt to clearly delineate the contribution of research vis-à-vis other factors, including extension, the farming systems and environment, and the sociopolitical, macroeconomic, and policy contexts.

Despite the difficulty in making generalizations for SSA, the case studies and the subregional perspectives (Chapters 3 and 4) provide considerable evidence for the hypotheses presented in Chapter 2. This chapter addresses these hypotheses utilizing the findings from the case studies.

CENTRAL HYPOTHESIS

There is substantial evidence from virtually all the case studies, as well as from other countries in the region, that innovations produced by research have resulted in significant improvements in maize production and factor productivity in SSA. These improvements have been associated with a major expansion in maize production since the 1960s, averaging 2.6% annually for the SSA region.

> **Increased Productivity**
>
> Innovations for maize have increased the productivity of land and labor across a broad range of farming systems.

The statistical evidence at national and regional levels suggests widespread improvements in yields. The rate of increase in yield since the late 1960s averages less than 1% per annum for SSA, but the impacts of innovation on land productivity are partially obscured by expansion into marginal zones, higher intensity of cultivation over time, and decline in soil fertility.

This is illustrated by the experiences in Kenya (Machakos district), Malawi, and Zimbabwe during the 1980s. Seasonal crop yields, however, are not a major reason why many farmers adopt innovations. The evidence strongly supports the proposition that research contributed to increases in returns to both labor and land, and thus to the competitive position of maize in relation to other enterprises. The full magnitude of these benefits is obscured by the difficulty of measuring the complete range of impacts.

In each of the case studies an effort was made to understand farm-level decisions on adoption from the perspective of productivity changes. Economic logic implies that farm families will adopt innovations, as opposed to simply expanding area devoted to a specific commodity, in order to either increase productivity or at least reduce the risks of losses from negatives such as drought and disease. Data in many instances is limited to on-farm yield trial results comparing improved varieties with local cultivars, but these strongly suggest that improved seed and fertilizer, especially in combination, significantly increase productivity. While such results are hardly surprising, the case studies provide evidence that large numbers of farmers have been able to realize significant portions of these benefits in their own farming systems.

Other factors, including political conditions and policies on prices and markets, input supplies, and the nature of the farming systems involved, have clearly influenced the magnitude, scope, and timing of the expansion of maize production. Innovations, particularly improved germplasm, are associated specifically with improvements in productivity. Possibly the most intriguing dimension of the MARIA study is the better understanding of what farm families in different circumstances actually do as a consequence of increases in productivity. This set of responses, which frequently seem to offset one another in higher levels of statistical aggregation, define impact.[1]

There is considerable variation geographically in the character and magnitude of productivity increases, even within a single country. The increases in yield have been most dramatic in maize-dominant, high-potential areas such as those found in Western Kenya and Zimbabwe. In contrast, labor productivity appears to have been the most important feature for farmers in Central and West Africa, which generally have less land pressure. Further innovations, including short-duration, drought-evading varieties, appear to have been instrumental in the expansion of crop production into areas previously used primarily for grazing in Machakos district in Kenya and in drier areas of southern Africa, thus changing fundamentally the productivity of this land. However, such expansion in marginal areas tends to depress national yields.

1. These issues are examined further in Chapter 6.

INDIVIDUAL ISSUES

This section summarizes the case-study findings with respect to the seven issues presented at the end of Chapter 2 (Context). The issues relate to (i) the nature and size of impacts found in different situations, especially maize-dominant farming systems compared to others, and large, commercial farmers vis-à-vis small producers; and (ii) the roles and effectiveness of various factors, including research, extension, and policies.

Magnitude of Production Increases

All the case studies provide at least qualified support for the notion that the character and magnitude of impact is related to the initial position of maize in the farming systems and diets. East Africa accounts for over half the growth in sub-Saharan output since the 1960s, while Central Africa, where maize is a secondary crop, has contributed only 10%. Nevertheless, the case studies suggest that the relationship between the role of maize and the nature of production increases is not as close as expected.

> Improvements in maize production and productivity attributable to innovations are greatest where maize is the primary staple food.
>
> **Accepted with Qualifications**
> **(Nigeria, Malawi)**

The major expansion of maize in Nigeria has occurred in the north, an area where maize was previously an insignificant crop. In contrast, improvements in production have been less impressive in the south, where maize continues to be a secondary staple and is regularly traded in urban markets. The experience of Nigeria illustrates the advances that can be achieved when appropriate technology and favorable ecological conditions (the Northern Guinea Savannah zone) are linked with strong demand and adequate market infrastructure.

The progress in Malawi compared to that of Kenya demonstrates the potency of demand for research. Maize is more important in Malawi than Kenya, although both are maize-dominant food economies. Yet production increases to date have been greater in Kenya than in Malawi. The difference is partially explained by the early impetus given to Kenyan maize research and development by settlers in the 1950s. In both Kenya and Zimbabwe there was a demand from the commercial maize producers for research results and high-quality seed, and this clearly influenced the timing and levels of effort for maize research as well as its character. The research associated with current advances in maize in Malawi started more than a decade later, and the spread of improved germplasm is still very much in progress.

Further, the results suggest that a distinction should be made between increases in production and productivity, particularly in maize-dominant systems. One can expect greater receptivity to productivity-increasing innovations for maize where the overwhelming majority of farmers devote most of their resources to maize production. However, the extent to which such productivity increases translate into greater production will depend on the proximity to food self-sufficiency of individual households and the country as a whole. It will also depend on the returns to resources compared to alternative activities, farm and nonfarm. Resource-constrained households in maize-dominant farming systems characteristically strive to fulfill at least a portion of their own consumption requirements, beyond which their resource allocation decisions are guided by the relative returns to different enterprises. An innovation for maize may assist a household to meet its consumption requirements with less land and labor, thus releasing some resources for other activities. This response is explored further in Chapter 6 (Lessons).

Area expansion has been an important component of maize production increases in all the case-study countries. For the entire SSA region, area increases accounted for roughly two-thirds of the 2.6% average annual growth rate of maize production since the 1960s. Predictably, area expansion is more important than yield increases in the West and Central African subregions. The situation is reversed for East Africa where yield increases account for approximately 60% of the growth in production.

Consistent with expectations, most of the expansion of maize production appears to have been at the expense of other farming enterprises, rather than through expansion of areas under cultivation. These shifts were stimulated by innovations as is discussed below.

The major exception among the case studies is Zaire, where area planted to maize expanded. In Shaba Province, forest lands were cleared and planted to maize largely in response to improvements in transportation that linked production areas to the urban markets. Maize technologies were available and being actively promoted by PNS, but the relative roles of innovations, road building, and markets in accelerating the expansion of area under cultivation is not clear. It seems probable that most of the area expansion would have taken place, even without improved maize technologies.[2]

The relationship between expansion in cultivated area and innovations for maize is clearer in the case of Machakos district in Kenya. The availability of short-duration, drought-evading varieties, especially KCB, are directly associated with the expansion of maize production into drier areas previously used for grazing.

2. The fact that new seeds were not widely used at this time, and that fertilizer was generally not used on newly cleared land, tends to support this proposition.

Innovations and Competitive Position of Maize

Technology has improved maize's competitive position vis-à-vis other commodities in all the case-study countries. The response to this improvement in relative profitability depends on the commodity's importance in the farming systems. While regions where maize is less important will expand area devoted to maize, maize-dominant farming systems are most likely to shift resources out of maize into other enterprises.

> Innovations have improved the competitive position of maize vis-à-vis other commodities.
>
> **Accepted**

This may occur in Malawi as the use of innovations continues to spread, but the evidence from Kenya on this score is quite mixed. New varieties are associated with the expansion of maize production at the expense of grazing in the drier areas of Machakos; but elsewhere, particularly in the higher-potential areas, increased maize yields were used by farmers to shift resources to more profitable crops (e.g., coffee, tea and horticultural crops) while maintaining maize production for home consumption.

Evidence from Senegal, The Gambia, and Nigeria strongly suggests that farmers expanded maize area in response to the commodity's profitability vis-à-vis sorghum, millets, and groundnuts. Yield information suggests the differential was already there, but the new varieties and promotional efforts lent considerable momentum to the changes that took place. In addition, maize is attractive in West Africa because of its early-maturing characteristics, which enable it to contribute to food supplies during the "hungry period."

In Zaire, the increased profitability of maize production has provided farmers with income to expand nonfarm activities such as trading. In Senegal and Nigeria, increased income facilitated investments in farm capital such as animals and traction equipment, and the purchase of inputs.

Equity

Socioeconomic equity has been enhanced by agricultural research in general and maize technology in particular. Where prices have not fallen too far, cash-cropping of maize sold on the domestic market has helped redress urban-rural imbalances. Food-deficit rural households (who constitute a growing proportion of the total) and urban consumers benefitted considerably from improved supplies and lower prices than would have otherwise prevailed in the absence of innovations for maize. This is especially true in Malawi where most rural households are in a deficit position.

> Larger, commercial producers have gained proportionately more benefits from maize innovations than small, low-resource farmers.
>
> **Accepted, but**
>
> Medium to small farmers increasingly dominate total maize production and have gained substantial benefits, as have consumers.

Large commercial farmers within rural communities, particularly those in Kenya and Zimbabwe, were the first to profit from the advances in maize technology. In some instances they have played important roles in guiding the direction of research and the character of agricultural policies on prices, inputs, and trade (Anthony 1988; Blackie 1990). However, commercial maize producers are not important factors in maize production in most SSA countries. Efforts to promote large-scale production through state farms and private operations in Tanzania, Zaire, Nigeria, and Ghana have generally failed. In terms of gains per farmer, per hectare, or even per unit output, larger farmers have benefitted proportionately more than small-scale farmers. However, smallholders have more than caught up despite the high resource and management bias of the technologies. The share of small-scale production appears to have gained in relative importance throughout the region as shifts in pricing policies during the last decade have led to the rationalization of commercial maize production and a shift toward other crops by this group. In aggregate lower-income groups, producers and consumers have probably benefitted more despite smaller individual gains.

In West and Central Africa, maize technologies may have contributed to income disparities between rich and poor producers at the village level. Nonetheless, green maize has an increasingly important role in meeting the food and cash needs of poor households during the early harvest period. Both rural and urban consumers have enjoyed greater supplies and lower prices of maize.

There is no evidence that increased productivity has diminished the access of women or other disadvantaged groups to resources. Overall, women have benefitted from improved productivity and, where maize has replaced sorghum or millet, they have benefitted from the easier processing characteristics of maize. There is no indication that consumers, or laborers paid in kind, have suffered from changes in the nutritional value of improved maize varieties. However, disadvantaged groups continue to be discriminated against in terms of gaining access to inputs and credit associated with efforts to promote innovations, especially in Malawi.

Effectiveness of Research / Extension Linkages and Input Availability

In all case-study countries there have been concerted efforts to identify, adapt, and transfer maize technologies during specific periods of time, and these efforts are associated with the progress that has been made. Effective linkages between research and extension, sometimes in the form of functional integration within the same project, are critically important in understanding progress in maize production and productivity in Senegal, Nigeria, The Gambia, and Zaire. The linkages were also strong in Kenya during the 1960s and 70s, but have weakened since then. Linkages have been least impressive in Malawi, which may partially explain the slow rate of progress in dissemination of innovations.[3]

> The effectiveness of research-extension linkages and input availability are critically important in explaining successful experiences in maize technology transfer.
>
> **Accepted**

In Senegal, the Unité Experimentale spearheaded adaptive research as part of promotional efforts for maize in Sine Saloum. Although these began in the 1960s, farmers did not turn to maize in a major way until the 1980s. In Nigeria, the adaptive research work of IAR was a vital factor in the decision to include a promotional package for maize in the first ADPs in the Northern Guinea Savannah. In Zaire, although there were some tensions between research represented by PNM/CIMMYT and extension (PNS), the latter did integrate adaptive research activities for maize into its program,

3. The slow spread of hybrids in Malawi is traceable to a number of complex factors, as illustrated by the Malawi section of Chapter 3 and the full case study (Smale 1992).

and both sides helped ensure the availability of inputs.

Input availability is critically important in explaining the rate of adoption of innovations. Inputs were often supplied by the special projects (e.g., Unité Experimentale in Senegal; Funtua ADP in Nigeria) to complement the promotional work, but arrangements and availability often became erratic and unreliable as the projects came to an end. In Zaire, functional overlaps between agencies helped to ensure that inputs were delivered. In Kenya and Zimbabwe, the emergence of seed companies as participants in the efforts to develop new varieties partially compensated for the reduced performances of public sector research programs.[4] A rigid division of labor among organizations probably would have increased inefficiency given the high probability that one or more links would break down at critical junctures.

Policy Environment

All the case-study countries in varying degrees enjoyed policy environments that favored maize research and development, at least for specific periods of time. For the maize-dominant systems of East and Southern Africa this support is not surprising and, to a fair degree, has been institutionalized. However, pricing and marketing policies in several countries of the region, especially Zambia, have worked against producers in an effort to keep prices low for urban consumers. Further, pricing policies deliberately favored commercial producers in Kenya and Zimbabwe during the 1960s and 70s. Prices and markets have enjoyed a lack of regulation in most countries of West and Central Africa, in part because maize is less important as a food source in these parts of the region. However, governments in Zaire, Cameroon, Senegal, Ghana, The Gambia, and Nigeria have given priority attention to maize in the context of special research and development projects. Subsidized and readily available inputs are prominent features of virtually all these projects.

> A favorable policy environment is important in explaining the progress of maize production and quality.
>
> **Accepted, with Qualifications**

In terms of trade regulations the evidence is mixed, but possibly not of great overall significance. The major exception is Nigeria, where import bans on cereals greatly improved the attractiveness of domestic maize production in the late 1980s. In contrast, cheap maize imports into Senegal as feed and food aid are cited as a negative factor in efforts by the GTZ project in the Sine Saloum region to promote maize production for poultry feed.

In spite of favorable policies and programs for maize, the policy contexts in most case-study countries were less positive, and constrained agricultural research and development efforts. Zaire is the most extreme example of adversity among the case-study countries. The special research and development projects were essential in insulating activities from the general institutional environments and ensuring progress. In Nigeria, overall economic trends and policies worked in both directions. The oil boom pulled large amounts of labor out of agriculture, but expanded research and developments efforts and dramatically increased and improved the road network. There was also a growing market for cereals in the urban centers. Subsequently, import restrictions on cereals and government monopolies over input supplies worked in opposite directions in terms of stimulating production.

Research Management and Performance

The attention given to maize and the quality of that attention varies significantly among the

4. These seed companies, however, often contributed to the decline of the public sector agencies by drawing off some of the most capable research staff.

Maize research program performance is a function of the level of resources and the quality of management.

Accepted, with Qualifications

case-study countries. At one end of the spectrum is Kenya, where maize is a long-standing priority concern. For approximately 20 years (e.g., through the end of the 1970s) the Kenyan Maize Research Program was responsible for producing a series of innovations that underlie the progress in maize production in the country. There was effective collaboration between agronomists and breeders during the early period and strong motivations to produce results that would be useable by various classes of producers in different ecologies. Maize in Malawi has also received considerable attention for over a decade, and the Maize Commodity Team is possibly the strongest in the Department of Agricultural Research. The recent continuity of staffing and support that the team has received is beginning to translate into major benefits for maize producers and the country as a whole.

At the other end of the spectrum, maize attracted only modest attention by the research establishments in Senegal and The Gambia. Progress was made in these countries in part because adaptive research was an integral part of development efforts.

Zaire and Nigeria fall between the two extremes. Nigeria has a large national program, and the role of IAR was important in the initial transfer activities in the 1970s. IITA and CIMMYT activities in these countries have been a major positive factor, compensating in part for the uneven resources available to national programs. As the host country, Nigeria has received the major share of IITA's attention for maize in particular.

For Zaire, it has been difficult to sustain any national maize effort outside the special USAID- and World Bank-supported projects implemented initially under contract to CIMMYT and subsequently by IITA. The weakness of the national program and the turnover of staff in the projects have seriously limited the effectiveness of maize research, especially during the 1980s.

External Institutions and Support

External institutions and donor projects have provided a major share of the support for maize research and development efforts in all case-study countries and throughout the SSA region where progress has been observed. In some instances, however, donor support and external linkages were "orchestrated" by national programs rather than the other way round. Where maize was less important, and where research and extension agencies were less well-equipped to deal with the commodity (e.g., West and Central Africa), the role of external institutions and donor projects tended to dominate, at least during the early, formative periods. On balance, this involvement has been positive and, in some instances (e.g., Zaire) it is not clear what would have happened without it. For the stronger national programs (e.g., Kenya and Zimbabwe), the role of external institutions is important, particularly as sources of germplasm, but less critical to the implementation of research at the national level.

External institutions and support have been associated with most of the progress in maize research and development.

Accepted

6. Lessons

The confirmation of the central hypothesis of the MARIA study—that innovation has improved productivity—is not surprising. Maize was chosen because it was known that some progress had been made. The magnitude and diverse character of the impacts, however, exceeded expectations and provided a wealth of additional insights on the character of agricultural change in SSA. It was also predictable that the study would confirm that research has played a role in the changes that have taken place. The nature of that contribution, however, and its interplay with other factors such as extension, input supply, and the policy framework, suggests a number of qualifications in the conventional approaches to technology development and transfer in the region.

This chapter summarizes the major lessons, emphasizing those that differed in some degree from the expectations of the study team. The intention is to provoke reflection and debate on approaches to development in the SSA region, and how to more effectively understand what is happening to the agricultural sector in particular. The discussion is structured to address the two major dimensions of the study: impacts, and the roles of technology development and transfer (TDT).[1]

IMPACTS

Perhaps the single most important lesson of the MARIA study relates to the limitations of conventional approaches to assess the impacts of research. Measures of impact that focus exclusively on changes in area and yield of maize, particularly above the provincial level, are likely to miss significant portions of the contribution of innovations. Such measures reveal only part of the impact "iceberg," most of which is not easily discernable through national statistics. Obscured impacts are particularly likely for innovations that primarily improve returns to labor as opposed to land, such as mechanization.

The Impacts Iceberg

A significant portion of impacts are associated with improvements in returns to labor, reduction of negatives, and reallocation of resources that are not readily visible through available statistics.

Efforts to understand the adoption of innovations and adjustments in resource allocation at the household level provided intriguing insights into the nature of farmer decision making, as well as the direction of the impact "trail" or sequence. The adoption of an innovation by a farm family normally improves productivity and provides them with an opportunity to make adjustments in resource allocations and consumption patterns.[2]

1. Insights from the MARIA study also touch on the measurement of impacts and, more importantly, the targeting of research toward enhancing impact. The problems associated with current measurement approaches and possible alternatives are the focus of a MARIA Working Paper by Elon Gilbert and Marie-Therese Sarch.

2. The reduction or avoidance of a negative, such as the effects of pests and diseases, implies little or no change in factor productivities per se compared to "nor-

The observed adjustments in resource allocations do not conform to expectations in all instances. Conventional economic logic suggests that improvements in productivity for a specific commodity will attract land, labor, and possibly capital to purchase seed or other inputs into the production of the commodity. Area expansion has clearly taken place in virtually all the MARIA case-study countries, although there is some question as to the degree to which the expansion was influenced by innovations, particularly in Zaire and Malawi. However, where maize is already dominant and grown primarily as a food crop, as in Malawi and Kenya, the responses of individual farm families can vary considerably. Families that are already self-sufficient or become so as a consequence of adopting the new technology may opt to shift resources out of maize into other activities. Whether they do or not depends on the returns to maize production vis-à-vis the range of alternate uses of available resources, as well as the aspirations of the specific family. Clearly, some farmers may find it is in their interests to produce maize for market and will expand production accordingly, but others may decide to use the resources "saved" from productivity gains for other purposes.

In essence, the maize technology alleviates to some degree the constraint that a farm family faces in meeting at least a portion of its own food requirements. Once that objective is routinely met, a family may expand resources devoted to other activities, both to improve incomes and achieve nonfinancial objectives (e.g., religious activities, schooling). Thus, in Malawi or Western Kenya for example, the impacts from maize innovations might take the form of a combination of higher yields, declining area, and increases in the production of maize that are roughly equivalent to population growth.

Resource Allocation

The effect of innovation on household resource allocations is a function of the position of maize and where a family stands in relation to its food production objective, as well as its perceptions of returns to alternate activities. In maize-dominant systems, farmers may use innovations for maize to "save" resources for reallocation to other enterprises.

The importance that many households attach to meeting their own food requirements is generally recognized. What is less well understood is the relationship of this objective to technology adoption and subsequent adjustment in resource allocations. In considering an innovation, farm families may be as interested in "saving" resources, as in the innovation's potential to increase incomes directly. This perspective may or may not be implicit in the themes and assessment criteria utilized by researchers, but the results of the MARIA study strongly suggest that it should be, as is examined further in the second section of this chapter.

The case studies suggest three qualifications to the preceding discussion. First, a growing number of farm families in SSA depend on the market for meeting a portion of their basic staple food needs. In some instances, as in Malawi, they have little choice given the shortage of land. Many farm families, however, have deliberately opted to produce other commodities or engage in nonfarm activities rather than meet all their own food needs. This "trend" may imply greater confidence in markets to provide a portion of their requirements at affordable prices. In addition, deemphasizing food crops reflects a family's perception that they will be better off as a consequence. For many farmers, shifting an increasing portion of resources away from food production has been a

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mal" levels. However, such levels are higher than would have been realized in the absence of pest- or disease-tolerant varieties, for example. In such instances, an innovation may simply avoid adjustments in resource allocations that farmers would probably make in an effort to counteract the effects of the negatives, such as shifting to other commodities that are less susceptible.

Diversification of Diets

The expansion of maize in areas where it was not traditionally important reflects a willingness to diversify diets, especially where food expenditures and/or resources devoted to food production can be reduced in the process.

continuing pursuit for many years. The distinction between cash and food crops is becoming less relevant. Technological changes for food crops, especially those which improve the stability of production, can be viewed as a means to accelerate this process.

Second, the dominance of traditional staples is often more a function of poverty than food preferences. In recent years, maize has become increasingly important in the diets of Nigerians, Senegalese, and Ethiopians, reflecting consumers' willingness to make changes, especially if they can reduce their expenditures on food. This dietary diversification should work in favor of maize in parts of the region that are suitable to its production but where the commodity is still relatively unimportant. On the other hand, poverty, drought, and advances in technologies for other coarse grains may favor the expansion of commodities such as sorghum and millet at the expense of maize in portions of East and Southern Africa.

Third, improved cultivars may differ significantly from local varieties in the eyes of producers and consumers. They are a similar, but not identical, commodity. In Malawi, until the recent release of new semiflint hybrids, local flinty varieties were grown to meet household food needs, while dent hybrids were produced for sale. As food, the hybrids had the added benefit of being a reasonable, but less-than-perfect substitute for local maize, yet farmers treated the dent hybrid more as another commodity than as a substitute for local maize. This difference becomes progressively less important as household food preferences and the characteristics of improved cultivars converge. In Kenya and Zimbabwe there was little difference from the onset, which greatly speeded adoption, while the divergence constrained adoption in Malawi. This distinction is less significant where farmers expand production primarily as a source of cash as in Zaire and northern Nigeria.[3]

New Varieties or Commodities?

The characteristics of new maize varieties may be sufficiently different from locals that farmers regard them as different commodities. Hence, the decision to produce locals for food and HYVs for sale in some countries (e.g., Malawi).

The Environment

Crop expansion, to feed a growing population, is rapidly eroding Africa's savannah woodlands and rain forest. Maize yield improvements reduce this somewhat, but maize in the Shaba highlands contributed to deforestation.

Maize expansion, like all extension of cropping areas in Africa, has negative environmental consequences. Croplands are eroding dry-season pastures and woodlands in arid areas and invading the rain forest. The root cause is not maize or innovations, but population pressure. Where improved maize has increased the productivity of cropped land, it has partially offset growing stress on the environment. In Zaire, however, the profitability of maize production in medium- and high-altitude rain forests has meant that farmers clear land specifi-

3. Although the farmer interviewed in the Funtua area of Nigeria (Malam Abdulahai) stated that he uses improved varieties for sale and local varities for home consumption.

cally to plant maize. The challenge to researchers, government decision makers, and local communities is to define the combination of policies and technologies that can bring about a greater convergence of individual and societal benefits in approaches to land use.

TECHNOLOGY DEVELOPMENT AND TRANSFER

The record of maize TDT in SSA consists of a number of bright spots and many missed opportunities. In nearly all the case-study countries major progress in maize TDT is traceable to specific individuals and time frames. These "windows of creativity" were brought into being and sustained for periods of time more by the force of personalities than by money, infrastructure, and institutional logic. The latter are certainly required, but can be replicated in successive research projects. Scientific leadership and conditions that foster creativity and performance are much more than the sum of training, technical assistance, capital equipment, and operating funds.

> **Windows of Creativity**
>
> A significant portion of the progress in maize research is traceable to periods or "windows" in which individuals combined with conditions that fostered creativity and performance..

The discouraging aspect of the MARIA findings is the state of the NARS. Performance levels of research institutions, particularly at the national level, generally appear to be worse now than they were in the past, when many of the major advances in maize technology were made. Large numbers of African researchers have received training, but the NARS themselves have not been able to create the environments necessary for productive research. High attrition rates among the most able staff are associated with poor conditions of service, and are a major factor in low performance levels. However, the chronic underperformance of most NARS relative to expectations is also associated with serious deficiencies in management and a general lack of accountability that permeates public sector institutions in most SSA countries.

> **Redundancy**
>
> Redundancy in services, particularly under adverse conditions, has been critically important in achieving progress in such areas as input supply and promotional activities.

Redundancy is frequently regarded as something that should be avoided; numerous reports cite functional overlaps and call for stricter divisions of labor. Yet the experiences in several countries, especially Zaire, strongly suggest that efforts to strictly define R&D responsibilities along institutional lines may be misguided. Where institutions function poorly, they are able to link and coordinate even less. A degree of redundancy has been critical in maintaining momentum of development efforts and achieving impacts. This appears particularly true where conditions for development are generally poor. Although redundancy can be wasteful, it can also help ensure that progress takes place under adverse circumstances.

Maize development projects have often integrated both research and extension responsi-

> **Integration and Linkages**
>
> The functional integration of adaptive research, promotion, and input delivery within the same organization has been more effective than efforts dependent on the coordination of different actors through linkage arrangements.

bilities. Such projects have been justly criticized for operating outside existing organizational structures and not contributing to sustainable institutions. However, in terms of impacts on the production and dissemination of innovations for maize, these special projects, which often survive for a decade or more, compare favorably to efforts that depended on coordination of several institutions through formal and informal linkage arrangements.

In summary, MARIA provides several insights that can help guide agricultural research development efforts for the region in the current decade. The agricultural sectors have experienced much more change than national production statistics and casual observation might suggest, and innovations for maize have played an important role in this process. The results confirm the vital role of agricultural research in producing the stream of productivity-enhancing technologies required for growth and development in the region. Given the political and socioeconomic contexts found in most SSA nations, however, replicating and sustaining the conditions that led to advances in maize research and technology transfer remains a major challenge. Although there are still areas where available technologies can spread rapidly with moderate adaptation, particularly in those regions that have been isolated by prolonged periods of unrest, research agendas are growing in complexity and, in the context of African farming systems, few commodities or subject-matter areas have as many inherent advantages as maize.

PROSPECTS

While our understanding of research needs has improved substantially during the past decade, the capacities of many NARS remain low or are diminishing. In many instances the performance levels of NARS have not responded to major institutional development efforts. The conditions that fostered achievement and creativity in maize research in specific countries (e.g., Kenya and Zimbabwe) prior to 1980, tend to be the antithesis of those currently found in the public services of most African nations. In some countries structural adjustment policies aimed at controlling the scope and scale of government activities generally thwart the capacities and performance levels of research services, while in others, civil unrest has virtually brought all research activities to a halt. Frequently, national researchers leave key NARS institutions as fast as they are trained. Numbers seriously understate the impact of attrition on the quality and quantity of research by NARS, since those leaving include a high proportion of the most able.

These conditions have led some donors, including USAID, to question the utility of further support for agricultural research. Reductions in assistance to NARS have tended to convert negative appraisals into self-fulfilling prophecies. There is a serious danger that the considerable progress that has been made in developing the next generation of innovations for maize and other commodities, particularly at the adaptive end of the research spectrum, will be dissipated in the process. While classic forms of the Green Revolution are unlikely in SSA, there is substantial scope for further improvements in productivity through the research now in progress as well as the selective use of innovations already available. This is particularly true in countries that have been insulated from technological change by isolationist and perverse policies (Guinea), civil war (Mozambique, Sudan, Angola, Ethiopia), or neglect (Congo).

Is the glass half full or half empty? Despair is perhaps the easiest conclusion to reach. Yet that conclusion ignores the fact that significant progress has taken place in selected countries and commodities, often in the face of adversity. The qualified success of maize in Africa provides evidence that substantial benefits can and did flow from the investments in agricultural research. What might have happened if conditions had been more favorable? If only some of the negative factors had not been present? Zimbabwe, during the immediate postindependence period (1980–85), is a good illustration of the dramatic results that are possible when there is a strong confluence of favorable factors.

The discussion assumes that expectations for technology include improved incomes and food security, especially for low-resource farm families. A further supposition is that concerns about impact will continue. An important message of the MARIA study is that the nature of change and transformation in SSA agriculture is complex and frequently appears contradictory, particularly when viewed through national statistics. Discrepancies stem in part from the diverse responses of millions of farm families to adversity and opportunity. A commitment to better understand what is happening should resolve these questions, and prevent them from continuing to undermine our confidence in Africa's ability to progress. This should not necessitate a major increase in resources available for monitoring, evaluation, impact assessment, and adaptive research, provided there is better synchronization of these activities within institutions and projects. In addition, there is considerable scope for expanded participation by extension services, NGOs, input companies, and farmers themselves, using the range of approaches that have been developed by FSR/E projects in particular.

How good a guide is the past for the future? Using hindsight, the MARIA study has shown that major efficiencies could have been realized in research investments. As with education and curative medicine, our institutional models for NARS were probably inappropriate for most of SSA. Yet quality research resulting in impact *did* take place under a variety of conditions and structures; for given periods of time, windows existed that fostered scientific creativity.

There will be a continuing role for NARS in this process, but the nature of that role is likely to differ substantially between countries depending on their policies, priorities, and capacities. Fresh frameworks for the structure of sub-Saharan agricultural research are likely to emerge as individual NARS gain a better understanding of their comparative advantages and the ways in which they can both enhance their participation in, and their service from, regional and international institutions and networks. New models must, above all, offer hope. They must change the negative or even cynical perceptions that researchers, national governments, and donors currently have of their NARS. Otherwise, the plans "will do little more than restructure mismanagement, reallocate frustration, and define problems for which no solutions will be forthcoming."[4]

What that new framework might look like is well beyond the scope of the MARIA study. The efforts that national governments and donors are now making through the Special Program for African Agricultural Research (SPAAR) and selected regional programs offer considerable promise for the future. The deliberations to date reflect a more realistic assessment of the limitations of NARS, and a willingness to explore new modes of regional collaboration in which emphasis is placed on enhancing the performance and contribution of African scientists. Institutions, whether they be IARCs, NARS, or some new form of regional collaboration, are a means to this end.

The MARIA study offers two suggestions for the future. First, we should reassess approaches to strengthening NARS, giving special attention to improving their performances in the face of adversity. Conventional approaches routinely seem to require better political and socioeconomic contexts than much of Africa is likely to offer before the end of the century. Rates of research failure can be reduced through avoiding debilitating interruptions in staffing and resources for high-priority activities. Second, the new frameworks should

4. From Chapter 2, Volume I, "National Agricultural Research Strategy and Plan for Uganda," ISNAR, The Hague, 1991.

emphasize human resource management systems that are guided by accountability, stewardship of innovations, performance, and, above all, creativity. Although training should continue, the focus should shift to enhancing the performances of staff at post. National and external research institutions can collectively produce the innovations that will move Africa forward. Towards this end, ways must be found to open more windows for the best of Africa's researchers to be creative in order to accelerate the flow of innovations required for development.

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Annex A

Scope of Work (SOW)

Impact Assessment of Commodity Research in Sub-Saharan Africa

PURPOSE

Two teams of social scientists and agronomists will conduct an in-depth investigation of the impact of agricultural research on the production, consumption, and trade of two major commodities in sub-Saharan Africa. Maize, along with a second commodity (e.g., cowpeas, cassava, or sorghum) will be the focus of the studies.

For the two commodities, this investigation will:

- quantify and assess the quality of the agricultural research resources brought to bear on technology development and transfer in Africa;
- examine the patterns of technology adoption (soil, pest, and fertility management as well as varietal) associated with these commodities in Africa (perhaps in a set of contrasting countries);
- assess the trends in the roles the commodities have played in production, consumption, and trade in Africa over the past three decades; and
- assess the extent to which agricultural research has, or has not, contributed to the production, consumption, and trade of the two commodities and, in the latter event, determine what factors have outweighed agricultural research.

BACKGROUND

USAID has, for many years, provided important support for agricultural research in Africa by funding specific projects as well as providing "institution-building" support for national agricultural research systems; by core and outreach support agreements with international agricultural research centers working in Africa; and by ad hoc project support through Collaborative Research Support Projects (CRSP), the Science Advisor, and PVO mechanisms.

The impact of this support in terms of increased agricultural production, consumption, and trade is neither well-documented nor widely appreciated. Under the Development Fund for Africa (DFA), USAID has been re-examining its experience through a number of evaluation approaches in order to assess where the support provided by USAID has both been cost-efficient and made a difference in peoples' lives. The expected outcome of these assessments is (1) a better understanding of the dynamics and performance of development efforts in key areas; and (2) derivation of lessons which need to be applied to improve performance in the future. Through the in-depth analyses of the impact of agricultural research on the production, consumption, and trade of two specific commodities as proposed here, it will be possible to gain insights important for our efforts in addressing the DFA objective of improving the potential for long-term increases in productivity in Africa as well as the more immediate task of improving food security in the region.

Maize has been chosen as a focal commodity for this in-depth analysis for several reasons:

- Maize is an important staple in the diets of Southern and Eastern Africans. In several countries, it has replaced sorghum as a traditional staple.
- Maize varietal development has been dra-

matic in certain cases (e.g., the hybrids of Kenya and Zimbabwe), but adoption of high-yielding varieties has been lower than expected in some environments (e.g., Malawi, Nigeria). Overall, average maize yields in Africa show only modest growth.
- Maize research has been consistent and important in national and international research systems for more than 30 years.

Similar thought will be given to the choice of a second commodity, but the emphasis will be on choosing something that is complementary to the insights gained from the maize study.

Duties and Responsibilities

Two multidisciplinary research teams will be constituted—one for each study. They will work for the Africa Bureau's Division of Agriculture and Natural Resources (AFR/TR/ANR) and will report to the Division Chief through the Head of the Planning and Analysis Branch. Travel will be required for approximately one-third the level of effort.

Main Objectives

In collaboration with AFR/TR/ANR and AFR/DP/PPE, the teams will delineate the present impacts of research on two commodities for Africa. The emphasis will be on actual household and national-level impacts on production, consumption, and trade. Therefore, coverage of the history of research on these commodities will be limited in depth and will focus most heavily on the past 10 years. This is not to be seen as a "history of maize research," but rather as a determination of actual impacts to the furthest extent possible.

The purposes delineated above will be accomplished for each commodity by the:

- collection of all secondary sources of data for information on the impact of commodity research on production, income, food security, natural resources, and trade;
- use of interviews and field trips to obtain primary information and additional secondary data from the international agriculture research centers (IARCs), networks, and national agricultural research systems (NARS) that are relevant to each of the commodities;
- determination on a country- then Africa-wide basis the probable impact of the commodity research utilizing the available information to the fullest;
- delineation of the necessary assumptions that had to be made to reach an estimate of impact so that the analysis could be redone at a future comparative date; and writing of two reports:
- a detailed report on data, methods, and results; and
- a summary report that can be read by non-specialists.

METHOD

Impact Defined

In order to assess impact, we need to agree first on what impact is. For this effort, impact will be defined as final, household-level impact on both the program and national level. The specific impacts will be a change in (or maintenance of) one or more of the following:

- Production;
- Income;
- Natural resource base;
- Food security; and
- Trade (national level only).

Approach

USAID needs an analysis and description, as much as possible in quantitative terms, of the impact agricultural research has had on these two commodities across Africa. This description should be based on the present situation versus what might be the situation if the new technology had not been available. In other words, what are the present, quantified impacts from agricultural research on maize and the second commodity across Africa?

Although the method chosen to describe impact will be driven largely by the data available, the teams' knowledge of the relationship between agricultural research efforts and impact, along with general economic theory, will also be important. The emphasis should be on providing information on the spread and impact of new technologies for these crops within Africa. In order to do this, some discussion of the history and process of agricultural research is necessary, but it should be limited in amount and focus mostly on the last 10 to 15 years. Such a historical perspective is only of value if it informs us of the actual impacts we see today in Africa from research on the two commodities.

Starting with the information available (such as rates of adoption or yields), the contractor will extend this to final impact using (1) the data available; (2) assumptions of present or future extension of the technology as necessary; (3) logic; and (4) economic theory to suggest impact.

In order to reach final impact, especially to describe national-level actual or expected impact, assumptions will have to be made. In all cases these assumptions should be delineated so as to inform possible future analyses.

MEMORANDUM

TO: Cathy Watkins

FROM: Thomas Hobgood AFR/TR/ANR

SUBJ: RSSA BAF-0135-R-AG-2200 as amended per PIO/T 698-0510-3-0619029 in the amount of $275,072, June 1990

1. The purpose of this memo is to notify you of several changes in the SOW of the subject PIO/T. These changes do not affect the level of funding.

2. The original SOW anticipated that two commodities would be studied:

   a) maize in Eastern and Southern Africa; and
   b) another commodity to be determined.

   It was envisaged that a multidisciplinary team would be assembled for each of the commodities, and that the study would be completed by July 31, 1991.

3. It has been decided to limit the study to only one commodity, maize, and to extend the analysis beyond Eastern and Southern Africa to cover the entire continent. Only one multidisciplinary team will be engaged under the leadership of Dr. Elon Gilbert. The study will now be completed by January 31, 1992.

4. The reasons for this change are:

   — the importance of maize and maize research in Western, Coastal, and Central Africa;
   — the need to obtain additional primary data from households through field visits and case studies;
   — the complex methodological problems that need to be addressed. This can only be done by looking more intensively at one commodity such as maize for which more work has been done relative to other commodities; and
   — in view of the methodological difficulties, the need for the preparation and careful review of an interim report so that all parties can agree on ways to deal with them.

Annex B

Methodology

The Maize Research Impact in Africa study (MARIA) assesses the impacts of maize research for sub-Saharan Africa. As such, the study examines the changes in maize production and productivity in the region and the role of research in producing these changes. The methodological challenge of the assessment lies both in the delineation of the impacts themselves and in the attribution of change to various causal factors, of which research is only one. Some of the changes, in fact, have little to do with adoption of innovations; for example, the expansion of maize area in response to changes in agricultural policies or relative prices.

This Annex describes the approaches used by the MARIA study team in completing the case studies and the main report. The Annex begins with a summary of the purposes and scope of the study. Subsequent sections treat (i) general approaches to research impact assessment; (ii) the case studies; (iii) measuring impacts; and iv) analyzing the roles of causal factors. The final two sections indicate the membership of the research team and the sequence of activities.

PURPOSES AND SCOPE

The purposes of the MARIA study are specified in the Scope of Work as follows:

- "quantify and assess the quality of the agricultural research resources brought to bear on technology development and transfer in Africa;
- examine the patterns of technology adoption (soil, pest, and fertility management as well as varietal) associated with these commodities in Africa;
- assess the trends in the roles the commodities have played in production, consumption, and trade in Africa over the past three decades; and
- assess the extent to which agricultural research has, or has not, contributed to the production, consumption, and trade of the commodities and, in the latter event, determine what factors have outweighed agricultural research."[1]

Further considerations relate to the principal audiences and possible uses of the study as follows:

- assist USAID and other agencies supporting agricultural research for sub-Saharan Africa (e.g., governments and donors) in understanding the consequences of productivity changes (or avoidance of adverse change in the case of pest- and stress-tolerant germplasm) that can be traced to research; and
- identify lessons from the examination of maize research experiences to provide guidance for future research and development efforts for African agriculture.

Although quantification is important in understanding the power of technological change, the objective is not to produce quantitative indicators of impacts from research such as rates of return (ROR).[2] Rather, priority attention is given

1. Extract from the Scope of Work (SOW) for the MARIA study. The complete text of the SOW is included in Annex A.

2. The MARIA study is explicitly enjoined not to utilize ROR approaches since this is the focus of the

to analyzing the conditions and relationships or linkages that have assisted research and the eventual dissemination of its results to significant numbers of farm families.

According to the initial SOW, the study of impacts from maize research was to focus on Eastern and Southern Africa. A companion study involving a separate research team was to examine experiences for a different commodity in Western Africa. Separate studies covering different commodities would facilitate comparisons but, after considerable reflection, it was decided that maize alone offered a variety of experiences, and in some senses was a different commodity in the context of cross-country comparisons.[3] Maize is the dominant staple food crop in much of Eastern and Southern Africa, but is of secondary importance elsewhere in the region.

The current study relies primarily on existing documents and data on maize research and development activities in selected African countries and external organizations, especially the IARCs concerned with maize (e.g., CIMMYT and IITA). This information was supplemented by interviews with key actors and informants with firsthand knowledge of specific experiences. Case studies were carried out in Kenya, Malawi, Nigeria, Senegal, and Zaire in which local collaborators participated in most instances. One or more team members made visits to CIMMYT in Mexico, IITA in Nigeria, and the Centre de Cooperation Internationale en Recherche Agronomique pour le Developpement (CIRAD) in Paris, as well as to the regional offices of CIMMYT in Kenya and Zimbabwe. Team members made at least one visit to all the case-study countries. Although the team made extensive use of data generated through a number of surveys, the MARIA study did not carry out its own formal field studies. However, team members utilized Rapid Rural Assessment (RRA) to selectively validate or update information and assist in forming judgements on the nature of impacts and the importance of various factors.

APPROACHES TO IMPACT ASSESSMENTS

A study of approaches to ex-post and ex-ante research impact assessment was recently undertaken by the Department of Agricultural Economics of MSU for USAID, which quite adequately reviews both methodological approaches and results with specific reference to SSA (Daniels et al. 1990). In addition to noting the general dearth of attention to formal impact assessments in Africa, the study examines the appropriateness of different methodologies for the region.

THE CASE STUDIES

The MARIA study utilized a case-study approach to examine a spectrum of experiences, including successes and failures. The case studies assembled and analyzed information in the following areas:

1. The nature of changes that it was hoped farmers would make;
2. The changes in productivity that actually took place, and their consequences or impacts on food availability, incomes, and equity;
3. The causal factors responsible for these changes (or the reasons for nonadoption);
4. The source of the improved practices involved and the nature of the research and development efforts aimed at generating,

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companion study by Michigan State University (MSU). However, reference is made to the findings of the MSU ROR studies insofar as these are available, especially since maize is a focus of the case studies in six of the seven countries (e.g. Kenya, Uganda, Cameroon, Mali, Malawi and Zambia).

3. The memorandum of July 9, 1991 (Hobgood to Watkins) details the changes agreed to in the SOW (see end of Annex A).

testing, adapting, and extending these practices.

SELECTION OF COUNTRIES

Each country has its own unique history, and in that sense is perhaps best viewed as a distinct personality rather than being representative of a broader set of experiences. For the MARIA study, the selection of case-study countries involved the following considerations:

1. The existence of an identifiable R&D effort including maize during some period since 1960, preferably involving the NARS; inclusion of a range of levels of effort (e.g., different sizes of maize improvement programs).
2. The availability of documentation on maize R&D for the country and data/analysis that could be utilized in the assessment of impacts;
3. Inclusion of a geographic range of countries (at least one country from each major geographic grouping within the SSA region) and different types of farming systems (e.g., both maize- and nonmaize-based systems);
4. Ease of access (proximity) to the base location of one of the study team members; and
5. The interest of the USAID mission and the local NARS, and their formal agreement to having the case study carried out in the country.

In addition, the selection of case studies was influenced by the choice of countries for the MSU ROR study. With the exception of Kenya and Malawi, it was decided to avoid working in the same countries, especially since maize was selected in six of the seven ROR case-study countries.

No effort was made to select countries on the basis of whether they were successes or failures, beyond insuring that some of the former were included. To a fair degree, the experiences of each country encompass examples of both.

The case-study countries include Senegal and Nigeria in West Africa; Kenya in Eastern Africa; Zaire in Central Africa; and Malawi in Southern Africa. Companion studies were undertaken for Congo (Brazzaville) and The Gambia.[4] Ethiopia was also selected for a case study, but the fighting that accompanied the change in regimes in Ethiopia in May directly affected the team member (Stroud) responsible for that country, and it was not possible to complete the research as planned. Information on maize R&D experiences in Ethiopia have been included in the Subregional Perspectives chapter of the main report.

CASE-STUDY APPROACH

The primary function of the case studies is to document the impacts from the technological changes in maize production and postharvest activities in specific countries during given time periods. The assessment indicates what actually happened as compared to the changes in maize production and productivity that might have prevailed without the introduction of new technologies. Indicators of impacts include changes in yields, areas and production for maize and competing crops, nutrition, incomes, trade, prices, balance of payments, equity and income distribution, and environment. These impacts are analyzed at five levels: regional (SSA), subregional, national, district or project area, and household, as illustrated by Table B.1.

The second function of each case study is

4. The Gambia was proposed as a case study, but USAID/Banjul declined to endorse use of study funds for the country. However, Musa Mbenga, the Head of the Upland Cereals Research Program in the Department of Agricultural Research, was interested in carrying out the study. Support was obtained from the Center for Research on Economic Development of the University of Michigan for The Gambia case study. USAID/Banjul concurred with this arrangement.

Table B.1. Levels of Impact Assessment

Level	Type of Impact	Source / Method
Regional (SSA)	Maize production	USDA/FAO/IBRD
	Subregions	Regional statistics
	Yield, area	With / without technology change comparison
	Cereal production	
	Food production	
	Food imports	
	AGDP, GDP	
	Balance of payments	
Country	All regional level indicators	
	Policies	Existing studies
	Regional equity	National statistics
	Institutions	Existing studies / key actor interviews
Project area / district	All country-level indicators	Project reports evaluations
	Environment	Key informants
		Special studies
	Income Distribution	
Farm family	Productivity changes	Farm management studies
		Project reports
	Income changes / allocations	Special studies
		RRAs
	Resource reallocations	Key informants

the analysis of causal factors that explain the nature and magnitude of the changes that took place including the research, policies, marketing and prices (inputs and output), and the farming systems themselves. The analysis seeks to show how a particular factor helped or hindered the impacts, but is not intended to be a review of agricultural development or the history of maize research in a country or for a specific institution.

ASSESSMENT OF IMPACTS

Defining Impact

The study examines three major types of impacts: socioeconomic, environmental, and institutional. Primary attention is given to the first two, and includes changes in (i) production and productivity; (ii) income; (iii) natural resource base; (iv) food security; (v) equity; and (vi) trade/balance of payments. Consideration of institutional impacts, specifically with reference to research organizations, is included as part of the analysis of the factors, but is not an explicit focus of the MARIA study.

Production is the most commonly utilized measure of change for agricultural commodities and thus is the initial indicator of impact. Production is a function of area and yield. The assessment of impact focused on comparing what actually happened (or at least what official statistics indicate happened) with what might have been the case without technological change based on assumptions for area and yield variables. The assumptions for the “without” scenarios consist of the following:

■ **Scenario I (Static Yield):** ***Assumptions***

- — Maize yields remain the same as the 1966–70 annual average; sorghum and millet yields are actual five-year annual averages.
- — Total area under coarse grains is the actual, but the proportions devoted to maize, sorghum, and millet remain the same as in the 1966–70 annual average.

A major part of the visible impacts from improvements in maize production are traceable to (i) yield increases; (ii) expansion in area; and (iii) shifts in area from other crops, primarily other coarse grains (sorghum and millet). This scenario basically extrapolates from the average situation found in 1966–70, allowing total coarse grains area to expand as it actually did, but holding the proportions among the three major coarse grains the same as the average 1966–70 period. The underlying assumption is that innovations for maize have favored that commodity vis-à-vis sorghum and millet, and have been the major contributing factor for the shift towards increased area in maize production. The areas where maize has replaced sorghum and millet tend to be the more well-endowed areas. Sorghum and millet were left in the less-productive areas in terms of moisture and soil fertility, and their national average yields declined in many countries as a result.

■ **Scenario II (Decline):** ***Assumptions***

- — Maize yields decline by 1% per year from the 1966–70 annual average; sorghum and millet yields are actual five-year moving averages.
- — Maize cropped area remains at the 1966–70 annual average per year with increases for sorghum and millet so as to make total area under coarse grains the same as the actual, each year.

The “decline” scenario assumes reductions in yield as a consequence of pests, disease, and declining soil fertility in the absence of technological countermeasures. Coarse grain area as a whole expands as actually happened. In effect, sorghum and millet were assumed to expand in place of maize.

Five-year annual averages for areas, yields, and production were used to smooth out fluctuations due to weather for the purpose of comparing actual figures with the two scenarios described above. Two sets of estimates or series for coarse grain production were calculated based on the above assumptions. These series are presented in Annex D. Figures based on these series are included in the main text, notably in Chapters 1, 3, and 4, as part of the discussions of regional, subregional, and country-level impacts. The figures are shown as graphs that illustrate the gap in production which might have resulted by the 1986–90 period from the nonadoption of technologies. The differences between actual maize production and the two “without technology” scenarios are the basis for generating a “gaps” table that estimates the impacts of technology on food production, AGDP, and balance of payments.

There are several variations of these assumptions that might be used where there was clear evidence pointing in a particular direction. The team members were urged to modify the assumptions where they thought alternatives made more sense. For Malawi, Zaire, and the Central African subregion, it was felt that the relationship between area changes for maize and other coarse grains was not sufficiently close to utilize the assumptions on substitution described in the scenarios. Hence, maize was treated alone.

Changes in maize production alone can be misleading. Technological change in farming systems where returns to labor and risk reduction are dominant considerations is less likely to produce easily recordable evidence of impact. For example, a commercial maize farmer is able to buy a tractor and expand area under cultivation, whereas a peasant farmer likely has a donkey, a cultivator, and a seeder. Maize production increases in the first instance, but not in the second. Factor productivity is profoundly affected in both instances, but the impacts are only easily measurable for the commercial farmer.

Impacts associated with technological change can escape or disappear from the agricultural sector almost immediately, especially where farmers are interested in reallocating resources to nonagricultural activities. Resource reallocation can, in fact, be a major motivating factor for the adoption of a specific innovation. Hence, the study also sought information on changes in factor productivity as revealed through input/output relationships (crop enterprise budgets). Evidence of changes in factor productivity <u>is</u> an impact. Such evidence does not solve the problem of measuring other obscure or invisible impacts, but together with information on resource reallocations (such as rural-urban migration) offers important clues as to which direction they went.

Other indicators of production and productivity are also assessed insofar as research contributed to change in a specific factor (e.g., enhancing the natural resource base or improving food security). However, to the extent that research has had an impact, it is generally expressed as some combination of i) changes in production and productivity; and ii) maintenance of production or reduction in losses in the face of adverse environmental changes (e.g., pests, drought, unfavorable policies and macroeconomic conditions). The latter area is difficult to measure, but important to consider with reference to technologies such as pest and drought tolerance or drought-evading varieties.

The assessment of impacts in the first instance encompassed all changes that have occurred in maize production, regardless of cause. This approach is dictated by the practical difficulties of making distinctions between changes that are the result of research as opposed to other factors, such as policy and climate. National area, yield, and production statistics commonly do not allow a distinction between changes traceable to the adoption of innovations as opposed to the effects of weather, pest problems, and cropping preferences.

The effects of variations in weather and pest problems can be reduced through averaging for five-year intervals and then examining trends over time. However, weather shifts can be long term as in the semiarid tropics (SAT) region of West Africa, and persistent pest problems can produce shifts in area.

Yield changes are generally associated with technological change, and in most of the case-study countries this was, in fact, the case. However, the successful spread of an innovation such as an improved variety or hybrid is often associated with an expansion in the area devoted to maize. To the extent that this expansion takes place primarily on medium- and low-potential areas relative to where maize was grown previously, average yields for a country may not increase as much as might be expected, or may even decline. Ironically, the more successful an innovation is in terms of adaptability to a broad range of environments, the less satisfactory national yield trends are likely to be as measures of impact. It is usually (but not always) safe to associate an increasing yield trend with technological change, but static or declining yields can be misleading, especially when they accompany major shifts in cropping patterns and expansions in maize production area.

RELATING PRODUCTION TRENDS TO CHANGES IN PRODUCTIVITY

The study sought to relate trends in areas and yields to productivity changes. Increases in yields are often an indication of technological changes traceable to research results. Land is relatively plentiful in large parts of Africa, however, and returns to other factors of production (e.g., labor and capital) are more important in the minds of many African farmers. As

Binswanger (1986) notes, the failure of researchers to consider this fact has contributed to a poor record of adoption of "improved" technologies which focused on yields.

Accordingly, the study also examined area expansion, especially where this appeared to have taken place at the expense of other crops. This may be the result of favorable policy changes for input and output prices. Such policy changes may have been facilitated by studies that should be considered part of the research process, even though conventional definitions of agricultural research in Africa usually focus on biotechnical studies.

The study sought evidence of reductions in costs and labor inputs per unit of output (through greater use of animal traction, etc.). It also looked for changes in crop calendars through the use of varieties of different maturities, which might help explain the expansion of maize production, but may not have had any positive impact on national yield statistics. The expansion of maize production into marginal areas through the development of new varieties and suitable agronomic practices can actually result in the lowering of national average yields, but represents a positive impact of research where total production increases as a result. Further, innovations such as the adoption of a shorter-duration variety as a means of increasing annual cropping intensities, or the widening of plant stand spacing to facilitate mechanical cultivation within and between rows, represent improvements in factor productivity that tend to *reduce* yields per crop.[5]

Data on changes in factor productivities in maize production in relationship to competing enterprises is often not readily available. While farm budgets were used where these were accessible, it was also necessary to make use of other indicators, including sales of inputs and data from on-farm trials and demonstrations where these exist. The study examined documentation on promotional efforts related to maize for indications of the type of changes that may have taken place.

Documentation on promotional efforts, input distribution, and trial results is critical in assessing impacts from innovations aimed at reducing negatives from pests and diseases. Actual sales and data on distribution of an innovation (if an input is required) can be an important indicator of the extent of use (e.g., MSV-resistant varieties). In addition, there is usually some basis (trial results) which can roughly estimate the losses that might have resulted without the use of the innovation. In most instances, however, the geographic spread of pest damage that might have occurred and extent of the innovation's use, such as a resistant variety, are almost impossible to estimate with any precision.

THE IMPACTS ICEBERG

As noted in Chapter 1, agricultural statistics can obscure or distort the perception of impacts both positively and negatively. The net effect of the range of considerations cited above is a tendency to underestimate the consequences of technological change or, in the case of elusive impacts, to miss them entirely. Thus the "iceberg" nature of impacts is methodologically challenging (see Figure 1.2 in Chapter 1). The magnitude and character of the impacts is influenced initially by the adjustments in resource allocations associated with the adoption of a new technology by farmers. Farmers who use a new maize variety, but do not expand area devoted to maize (either by additions to total area or reductions in fields devoted to other crops),

5. Actual examples illustrating each of these yield-reducing advances are included in the discussion of impacts in Chapter 4. Rwanda and Burundi provide additional examples of shifts to shorter-duration varieties in order to accommodate increased cropping intensities (Ziegler 1986; Haugerud and Collinson 1990). The use of the "care" system of cross cultivation in Senegal and The Gambia illustrates the adjustment of crop spacing to accommodate the substitution of animal traction for labor in weeding (Mills and Gilbert 1990).

have the most visible impacts. Virtually all the first generation of impacts come through to the national statistics in a clear form. The next generation of impacts involves farmers selling or consuming more maize. This impact is much more complicated to assess, but at least the front edge of impact is visible and relatively easily measured. As discussed below, it is hypothesized that the impacts of commercial farmers are generally more visible than those of small, low-resource farmers.

The next category of complexity (obscured impacts) involves farmers who make adjustments in land allocations among crops and/or expand maize area in response to the adoption of an innovation for maize. Assuming one can "track" where most of the land came from or went to (fallow or other crops), it is once again possible to estimate the first generation of impacts, although usually less precisely than with no change in area.

Finally, there are the farmers whose response to the adoption of innovation is to reallocate resources (land and/or labor) either to another agricultural enterprise (e.g., away from maize) or out of agricultural activities altogether. The example given above for animal traction is a case in point.

A second example involves farmers whose response to an innovation, such as an improved maize variety, is to maintain maize production at current levels using a smaller area and shift resources into a higher-return cash crop such as coffee. If this resource reallocation involves reducing the area under maize while the yield increases, the maize yield portion of the impact will still be captured by national statistics. However, if the best maize land is reallocated to the higher-value cash crops, or maize area and production are simply maintained by a combination of varietal change and shift of maize fields to less productive parts of the farm (e.g., land formally planted to other coarse grains), the net result could be little change in maize yields and area, and thus easily missed impacts.

Although logic dictates that these elusive impacts exist, it is often difficult or impossible to document them with any precision. Agricultural statistics were designed to monitor changes in areas, yield, and production—not to assess impacts. These statistics enumerate quantities at specific points in space and time, but rarely the relationships between those points. It is the relationships between the points that define the direction of impact and hence its nature and dimensions. If national statistics had been designed to measure impact (which they weren't), they would give more attention to the critical cause-and-effect linkages than they do.

Farm management studies can be of considerable assistance in providing indicators of changes in factor productivity associated with technological change, but once again, they are often less than satisfactory in defining impacts from the adoption of innovations.

ANALYSIS OF FACTORS

Tracking the Sources of Productivity Changes

Where there was evidence of shifts in factor productivity, the case studies attempted to trace this change to its source. Costs and returns may have altered due to price movements without changes in physical input/output relationships. Farmers may have simply expanded the area under maize in response to output price increases, but not adopted new technologies in the process. Price movements may be traceable to policy decisions in which research played a part, and examples of this type of research impact are noted. However, the study made a special effort to identify examples of technology adoption where research has played a role.

Where there was evidence of improvements in productivity, attention was given to the specific promotional efforts for innovations that might explain these changes. Documentation of promotional efforts were examined for answers to the following questions:

- Were there any interactions between researchers and farmers and, if so, what type? Did these interactions result in alterations in research directions? How have farmers modified recommendations? How were research and promotional efforts affected by these modifications?
- Did policies and interactions between research services and policymakers from NARS, ministries, and external agencies (e.g., donors, IARCs, NGOs) play a role in bringing about changes in research directions and levels of effort?
- What recommendations were part of the promotional efforts, and how do they relate to the changes that farmers appear to have made?
- What were the sources of those recommendations?
- What were the dynamics of interactions between research and extension and within the research services in the decisions about those recommendations?
- What were the details of the research activities associated with these recommendations which preceded the promotional efforts? What criteria did researchers use to select and evaluate specific research activities and how were these chosen?

Special attention was given to situations where promotion efforts resulted in increased production. However, the study also looked at research and promotional activities that focused on reducing potential losses due to drought and pests.

The Role of Research Institutions

The study is not intended to be a comprehensive review or history of maize research in the region, the case-study countries, or individual external institutions. Background information of this character is included to provide contexts for analyzing the role of research in specific situations. The focus is upon the research that proved critical to the subsequent adoption of the innovation and resulting impacts. Some research results were essentially "spill overs" that involved little input from researchers at the national level. In fact, a NARS may be an impediment by withholding a variety that it is unable or unwilling to test and recommend. Or a NARS may prove to be a serious bottleneck by insisting that all foundation seed be produced by the research service, and then be unable to handle the surge in demand associated with a successful varietal release.

The research capacities of NARS are often measured by numbers and skill levels of researchers. Serious questions are being raised, however, about the utility of body counts as measures of impact and performance (Eicher 1989). MARIA focused more on leadership; continuity and skill levels of staff; levels of operational costs per researcher; quality of support services; and the incidence of cash flow problems in relationship to research performance. Much of this information is not readily accessible or is anecdotal in nature, but nevertheless it provided important insights into the state of agricultural research management during the time frames in which specific innovations were produced and transferred.

ESTIMATING THE EFFECTS OF CAUSAL FACTORS

As with impacts, the analysis of factors starts with a description of what actually happened and goes on to "speculate" what might have happened if key factors had functioned more or less favorably. The speculation focuses on the possible effects of removing major distortions, regardless of whether they affect maize production and factor productivity positively or negatively. A distortion is an imposed condition that deviates significantly from a normal or equilibrium state. Government mandated prices are common examples of distortions, and their consequences for agricultural production and consumption have been the subject of studies in most African countries as part of economic reform programs. A civil war can also profoundly affect production, and is treated as a distortion in the MARIA study.

Each of the subregional sections in Chapter 4 includes a discussion of “Optimistic Scenarios” that speculates on what might have happened in specific countries and areas with more favorable conditions than were actually experienced.

MARIA STUDY TEAM

The study team membership and responsibilities are summarized in Table B.2.

Edgar Hunting provided assistance with the spread sheets for the “with and without technological change” scenarios. Collaborators on individual case studies included Victor Doulou (Congo), Koko Nzeza (Zaire), Daniel Karanja (Kenya), and Musa Mbenga (The Gambia). Joan Robertson and Christina Fairchild were responsible for editing and report production, respectively.

The Team Leader (Gilbert), who is resident in The Gambia, worked on the project from its initiation in early 1991 through to the submission of the final report in 1993. Lucie Colvin Phillips, resident in Brazzaville, worked with the project from its inception through mid-1992 when the draft final report was submitted. William Roberts, resident in Washington D.C., joined the project in mid-1991 specifically to prepare the Senegal case study, and subsequently assisted with the Zaire and Nigeria case studies as well as the Main Report. Marie-Therese Sarch, resident in London, joined in early 1992 to assist with the Kenya case study and continued through the finalization of the Main Report. Melinda Smale, resident in Malawi, prepared the case study for that country beginning in late 1991, and also provided assistance with the Main Report. Ann Stroud commenced work on the project in early 1991 at which time she was based in Ethiopia. Developments in the country directly affected Dr. Stroud’s family which, together with other responsibilities, made it impossible for her to complete the case studies for Kenya and Ethiopia as originally planned. She has, however, participated in reviews of the Kenya case study and the Main Report since then.

Table B.2. MARIA Study Team Membership and Responsibilities

Team member	Discipline	Responsibilities
Elon Gilbert	agricultural economics	Team Leader Main Report
Lucie Colvin Phillips	socioeconomics	Zaire, Congo, Nigeria, Kenya Main Report
William Roberts	anthropology	Senegal, Zaire, Nigeria Main Report
Marie-Therese Sarch	agricultural economics	Kenya, Nigeria Main Report
Melinda Smale	agricultural economics	Malawi Main Report
Ann Stroud	agronomy	Kenya, Ethiopia

SEQUENCE OF ACTIVITIES

The study was formally initiated in January 1991, although preliminary discussions involving the Team Leader and USAID Africa Bureau staff took place in late 1990. During the first phase, which lasted through July 1991, the study focused on maize in Eastern and Central Africa. During Phase II, the scope and budget of the study was expanded to encompass the entire SSA region and a total of five case studies. A preliminary draft of the main report was submitted to USAID in January, 1991. This was substantially revised, and a penultimate draft was submitted in July, 1992. A final version of the summary report was submitted in October, 1992 and accepted by USAID. The Main Report was presented to USAID in early 1993. The individual case studies and working papers are being revised and finalized during 1993. A chronology follows:

1990

September	Preliminary Discussions in Wash. D.C. (USAID Africa Bureau staff, Gilbert).

1991

January–March	Initiation of Zaire, Congo, and Ethiopian Case Studies (Phillips, Stroud). Travel restricted due to Gulf War.
April	Team Meeting in Kenya (Gilbert, Phillips, Stroud). Discussions with USAID/Nairobi and KARI on Kenya Case Study plans.
May	Initiation of Kenya study (Stroud); continuation of Zaire (Phillips); termination of activities in Ethiopia (Stroud).
June	Preparation and presentation of Phase I report and plans for Phase II in Wash. D.C. (Gilbert, Phillips). Participation in Workshop on Impact Assessment at Michigan State University (Gilbert).
July	USAID Africa Bureau concurrence for Phase II; Initiation of Senegal Case Study (Roberts).
August/September	Initiation of Nigerian Case Study (Phillips, Gilbert).
October	Initiation of Malawi Case Study (Smale).

1992

January	Visit to MSU for discussions on preliminary findings (Gilbert).
January/February	Preparation and submission of preliminary draft of main report in Wash. D.C. (Gilbert, Phillips, Roberts, Hunting).
March	Discussions with USAID Africa Bureau on preliminary draft (Gilbert).
April	Kenya case study reinitiated with preparation of Machakos study (Sarch).
May	Visit to CIMMYT in Mexico (Gilbert).
June/July	Preparation and submission of penultimate draft of main report (Gilbert, Phillips).
September/October	Assistance with prepara-

	tions for Impacts Symposium (Gilbert, Sarch).
October	Submission and presentation of summary report at Symposium on “Impacts of Technology on Agricultural Transformation in Africa” in Wash. D.C., Oct. 14–16 (Gilbert, Sarch, Roberts).
October/November	Assistance with DFA submission (Gilbert).
1993	
January	Final edit and production of Main Report (Gilbert, Sarch, Robertson, Fairchild, Hunting).
February	Finalization of Malawi and Kenya Case Studies (Smale, Sarch, Robertson, Gilbert).
March–December	Finalization of remaining case studies and working papers.

An effort was made to economize on travel and other expenses by combining work on the study with other assignments. This approach made it possible for team members to make most of the trips involved at little cost to the project. However, the time frame of the study was extended as a consequence.

Annex C
Innovations

The principal innovations that have affected maize production and productivity in sub-Saharan Africa fall into three major categories:

- Biotechnical innovations, including germplasm improvement, crop management, and postharvest techniques;
- Managerial innovations, including improvements in input supply, marketing and processing; and
- Methodological innovations, including changes in research methods (e.g., techniques that accelerate the screening of germplasm to disease vectors and various forms of Farming Systems Research [FSR]).

This annex focuses upon biotechnical innovations (technologies) including germplasm, mechanization (notably animal traction), soil fertility management, water management, pest management, and assorted agronomic and postharvest techniques that are the major products of research institutions. The specific issues and associated research themes for individual countries are summarized in Chapter 2 (Table 2.1) and discussed further in the individual case studies.

Managerial, institutional, and policy reforms are not usually thought of as innovations, but improvements in these areas have frequently been associated with research and special studies. Similarly, new methodologies have had major impacts on the efficiency of the research process as illustrated by FSR and screening for insect resistance. These "innovations" have profoundly influenced maize production and productivity in several countries, as is discussed in Chapters 2 and 3, but are outside the scope of this annex.

The following section examines trends in research themes and assessments criteria. Succeeding sections summarize the major types of biotechnical innovations for maize in SSA. References are made to the progress that has been made in selected research areas, although the discussion is not intended as a comprehensive review.

GERMPLASM IMPROVEMENT

The major research themes for germplasm improvement include improving yields, yield stability, pest and disease resistance, drought tolerance, storage and processing characteristics, and protein content. Advances generally produce yield improvements of 30–50% on farm and significantly more in high-potential areas under improved management (CIMMYT 1990). The degree of correspondence between these themes and the needs and constraints of various categories of farming systems in the SSA region has been a major factor influencing the extent of use of improved open-pollinated varieties (OPVs) and hybrids, and consequently the impact upon maize production and productivity.

Germplasm improvement (mainly varietal screening) has been a prominent element in all the case-study countries. However, there has been major progress in the development and dissemination of improved OPVs and hybrids (Table C.1).

Critics of the long-running dominance of germplasm improvement have charged that there is a tendency to define all problems in terms that can be addressed through breeding, rather than determining which approaches and disci-

Table C.1. Utilization of Maize Germplasm, Case-Study Countries

	Area (1000 ha)				
	Total	Local OPVs	Improved OPVs	Hybrids	Production (1000 MT)
Kenya	1,500	450	120	930	2,700
Malawi	1,343	1,163	20	160	1,343
Nigeria	1,600	219	1,381	-	1,832
Senegal	117	48	52	-	133
Zaire	1,200	852	182	166	870

Source: CIMMYT Survey Data.

plines might be most effective in producing solutions.

Hybrids Versus OPVs

The contrasting characteristics of hybrids and OPVs have important implications both for R&D programs and for efforts to measure adoption and impacts. Hybrid seed is normally imported or produced locally by a seed company, and should be replaced annually. Farmers usually make an initial purchase of improved OPVs, but then rely primarily on their own production as a source of seed. Farmer-to-farmer spread of improved varieties is also an important feature of OPVs. Finally, cross fertilization among local and improved germplasm is common which, over time, leads to changes in the genetic composition and characteristics of a variety. This happens despite efforts to have farmers replace their seed at regular intervals.[1]

The most commonly cited examples of improvements in maize production in the region have involved the initial widespread use of hybrids by Kenyan and Zimbabwean commercial farmers, but with large numbers of smallholders also participating (Gerhardt 1975; Rohrbach 1989). Trial results suggest that hybrids have a yield advantage over OPVs, although the gap diminishes at lower management and fertility levels.

Hybrids also tend to outperform OPVs under moderate moisture stress. The major advantage of OPVs is that farmers do not have to purchase seed annually. OPV seed tends to be significantly less expensive than hybrid seed.

The debate among researchers over the relative merits of hybrids and OPVs has been a major source of tension in the maize research community since the early 1970s. Those favoring OPVs argued that requirements for producing and distributing hybrids on a regular basis precluded their successful use in most African countries given the lack of stable conditions. Proponents of hybrids, on the other hand, cited the yield and greater stress-tolerant advantage, and countered with the success stories in Kenya and Zimbabwe, which were largely based on hybrids.

Opponents of hybrids felt that these two countries were the exceptions that proved the rule. Both countries had relatively well-developed commercial maize production sectors that could provide the core demand for a hybrid seed production industry. In addition, the re-

1. Farmers also use their own seed from hybrid production, but the differences in the results are often sufficiently dramatic to encourage the purchase of certified hybrid seed in the future. The process of varietal change through cross fertilization tends to be much slower and less dramatic with OPVs, depending upon how different OPVs (local and improved) are planted in relationship to one another and the manner in which farmers select seed from their own production.

search and extension efforts were generally of a higher quality than found elsewhere, so farmers could be more readily educated about the advantages of hybrids and the necessity of purchasing all their seed.

Through the 1970s the leader of the CIMMYT Maize Improvement Program (Sprague) was a prominent proponent of OPVs in Africa, although several of the countries in East and Southern Africa where CIMMYT has been most active are important users of hybrids. The hybrid-OPV debate was part of a series of counterproductive interactions among and within international research institutions that reduced the effectiveness of maize improvement efforts for the SSA region during much of the past two decades.

There is less debate on this issue today. Most West African countries continue to focus overwhelmingly on OPVs. Although some testing of hybrids does take place, serious efforts to develop hybrid seed production are few, and have generally failed (e.g., Senegal and Ghana). However, hybrids remain an important part of the research and extension efforts in many countries in East and Southern Africa.

Higher Yields

The relevance of breeding for yield under high management has also been the subject of considerable debate, often between researchers in the same institution. Adjustments in themes have been made over time and more attention given to pest resistance and performance in less favorable environments with lower management. However, research themes and particularly assessment criteria still generally reflect the primacy of returns to land under higher levels of management. As Low (1991) notes, this orientation is still common among FSR activities, in part because researchers are most comfortable approaching problems in this fashion. However, there is growing recognition of the need to consider area-specific constraints and flexibility of farming systems, even though these concerns are not always consistently and clearly reflected in the maize research program plans.

Questions about the appropriateness of breeding for yield are not limited to land-abundant and labor-scarce farming systems. Rwanda and Burundi are illustrations of land-scarce situations that have experienced a degree of intensification not found in most other parts of the region. Maize R&D efforts historically have focused on maximizing individual crop yields through the use of long-duration varieties. Serious issue has been taken with this focus in Burundi (Ziegler 1986) and Rwanda (Haugerud and Collinson 1990) on the grounds that criteria should properly focus on total net returns to land during a 12-month cycle, rather than per crop. This consideration dictated more attention to shorter-duration varieties and intercropping as a means of increasing cropping intensities and total factor productivity.

Protein Enhancement

Major efforts have been devoted to enhancing the quantity and quality of protein in maize through the breeding of high lycene germplasm. Although considerable progress was made, initially at CIMMYT and subsequently at IITA, the germplasm generally does not yield as well as the "normal" OPVs and hybrids. As a consequence, the work has been largely suspended at the IARC level. However, the French Centre de Cooperation Internationale en Recherche Agronomique pour le Developpement (CIRAD) is interested in continuing the effort, and has discussed with CIMMYT the feasibility of posting two researchers in Mexico to work on this with French government support.

If yield differences were small or insignificant at low management and input levels, then high lycene OPVs might be well suited for low-resource farmers. Production and factor productivity levels would be virtually the same as with other varieties, but nutrition could be improved. This is particularly important where maize gruel is an important weaning food for infants.

Resistance to Pests and Diseases

Substantial progress has been made in developing germplasm that is either resistant or tolerant to selected diseases. IITA identified strains that showed high levels of tolerance to MSV. Although there was considerable debate over the importance of MSV and the level of resources that should be devoted to this and other disease problems, the basic techniques have been developed by which MSV resistance can be added to existing germplasm, and selected conversion of germplasm pools is now in progress. Similarly, resistance to Downey Mildew (DM) has been identified, although the varietal screening process is more complex and costly. A major outbreak of DM in parts of Nigeria during the 1991/92 season should give added impetus to the dissemination of DM-resistant varieties in that country.

A major pest problem that appears less amenable to breeding solutions is *striga.* Both IITA and CIMMYT Maize Research Programs have mounted efforts to search for *striga* resistance. Simultaneously, but with limited interaction, FAO and ICRISAT have been working on ways of dealing with *striga.* Little progress has been made in coordinating various approaches to this problem, or to objective assessments of what the most promising mix of research strategies might look like. Institutional and disciplinary frontiers have discouraged this in the past, but lower budgets and greater interest in results may encourage collective reflection in the future.

Stress Tolerance (Drought and Low Fertility)

For all its positive features, maize does not perform particularly well under lower levels of fertility and moisture. Research has given increased emphasis to short-duration varieties with a range of characteristics, even though the yield potentials are less. The shorter-duration varieties escape the stress of drought at the beginning or end of the rainy season by simply avoiding it altogether. However, maize varieties are generally highly susceptible to moisture stress at critical points in their growth cycles, regardless of the total days to maturity. Similarly, at lower levels of fertility, performance of maize germplasm is uniformly poor.

There have been frequent calls for maize improvement efforts to focus more on these issues since they address the conditions and constraints of low-resource farmers in marginal areas. Some researchers question the practicality of pursuing such themes, and are doubtful that the results will be able to compete with sorghums and particularly millets, which are well suited to drought and low fertility. Many farmers have found maize an attractive alternative to sorghum and millet in drier parts of the region that were supposed to be beyond the limits of successful maize production. However, improvement efforts for sorghum and millets, especially at the Sorghum and Millet Improvement Program (SADCC/ICRISAT) in Zimbabwe, have produced germplasm that in the future may shift the balance away from maize in the marginal areas. In any event, upgrading the performances of sorghum and millet in these ecologies appears a less daunting task than it does for maize.

Processing and Preparation Characteristics

Improving processing and preparation characteristics has not historically been a major focus of varietal improvement efforts, but has assumed greater importance in selected countries in recent years. Differences in processing characteristics have been cited as a major reason for the slow adoption of denty hybrids in Malawi, and for the continued use of selected local varieties elsewhere. A major lesson from the case studies, however, is that differences tend to become less important over time with a convergence between tastes and the characteristics of improved germplasm, especially where significant quantities enter the market.

OTHER BIOTECHNICAL INNOVATIONS

Other categories of biotechnical innovations which have been the focus of R&D efforts for SSA include crop management research and mechanization. The former includes a range of agronomic practices related to soil fertility, moisture conservation, pest management, and other assorted improvements in factor productivity (e.g., spacing, time of planting, weeding, intercropping, etc.). Mechanization encompasses research on draft animals as well as equipment.

Despite the acknowledged collective importance of these innovations, they have frequently received less attention by research and evaluations of maize improvement efforts. In contrast to germplasm, crop management and mechanization are commonly not specific to one commodity, and information on adoption is thin or nonexistent. Further, the organization of research along commodity lines has reinforced the primacy of germplasm improvement and the dominant position of breeders in the research hierarchy. This has had important consequences for the manner in which research themes were defined and pursued and the attention given to topics other than germplasm improvement.

Mechanization

Mechanization, including tractors and animal traction, has been an important part of efforts to improve maize production and productivity. Virtually all the operations associated with maize production are relatively easily mechanized (harvesting is a qualified exception). Commercial farmers using tractors have benefitted most from advances in maize technology. These farmers are located primarily in Eastern and Southern Africa, but are increasing in some areas of West Africa that are most suitable for maize production (e.g., the Guinea Savannah in Nigeria).

The suitability of maize production to farming systems using animal traction (particularly in Mali, Senegal, and The Gambia), also contributed to its transition from a backyard garden crop grown virtually entirely by hand, to a competitor with other coarse grains and oilseeds on upland fields.

Most attention in research has been devoted to developing equipment suitable for use in animal traction systems. In the past decade attention has turned somewhat to the animals themselves, including equines (donkeys and horses) as well as oxen. Equines, particularly donkeys, are less expensive and more suitable for transport than oxen. They have received little attention in research and promotional programs, however, despite their popularity with small, low-resource farmers. Equines have no resistance to trypanosomiasis, and suffer from a range of diseases, including lymphagetis and African horse sickness, which limits their productivity, particularly in the higher rainfall areas. Advances in health care for equines offers considerable promise for decreasing the costs of animal traction.

Soil Fertility Management

Low soil fertility has been recognized as perhaps the single most important constraint to improving maize production in virtually all the case-study countries. Inadequate nitrogen in particular is cited as the major reason for the yield gap between research station and farm performance of improved germplasm. Most OPVs, and especially hybrids from research, have genetic potentials that exceed 7 MT per hectare, but small farmers using these varieties rarely average more than 2.5 MT. In some areas, notably Senegal and The Gambia, the expansion of maize in upland fields at the expense of groundnuts and other coarse grains has been limited by soil fertility as well as moisture-holding considerations. Maize cannot successfully compete with millets outside the more fertile "inner fields" that have higher organic content and moisture-holding capacities. The high quality is traceable in part to the practice of tethering livestock on these fields.

Considerable effort has been devoted to trials and demonstrations of inorganic fertilizer on maize throughout the region. Promoting increased fertilizer use has been a theme of FAO country projects in most countries for more than a decade. However, availability and price are increasingly more important constraints than a lack of understanding on the part of farmers. Government monopolies of fertilizer importation have routinely malfunctioned through mismanagement and corruption.

Reforms, including the breaking up of statutory monopolies and the reduction of subsidies, have achieved mixed results. Many farmers are now unable or unwilling to buy fertilizer due to higher prices. While further improvements in marketing efficiency could bring prices down, trends in supply and demand in world markets will increasingly influence effective demand in SSA.

Attention has turned to alternative measures for maintaining and improving soil fertility, including rotations, intercropping, and use of organic fertilizers. Agroforestry and alley cropping with nitrogen-fixing species are now major themes of several projects throughout the region, including virtually all the case-study countries. Research is also continuing to adjust fertilizer recommendations to the needs of prevailing rotations (e.g., millet/groundnut rotations in Senegal and The Gambia) rather than focusing on single crops. Research by the Maize Commodity Research Team in Malawi has identified serious micronutrient deficiencies (boron and zinc) in as much as 80% of farm land in the country, the correction of which could contribute to a major improvement in maize production and productivity in the medium term (Wendt 1992).

Moisture Management

As noted above under germplasm improvement, there has been some effort to screen varieties for tolerance to moisture stress. Aside from the obvious advantages of short-duration varieties, there has been little progress on this front, and there is question whether breeding is an effective means of addressing the problem. The major "finding" which farmers already know, is that if one does grow maize in drought-prone areas, soils with better moisture-holding characteristics are highly preferable. The more sandy upland fields, which characterize much of the farm land in Senegal, Mauritania, and The Gambia, are unlikely to sustain a successful maize crop even with fertilizer since moisture and nutrients rapidly retreat below the root zone.

Maize has achieved some success in irrigation schemes in drier areas, particularly in the Sahel in West Africa and in parts of East Africa. Maize also responds well to supplemental irrigation in dry areas during the wet season. The Institut Senegalais de Recherche Agricoles (ISRA) and CIRAD are collaborating in work on irrigated maize in the Flueve region of Senegal (Rouanet 1985). Wehelie (1989) has documented the dramatic expansion of maize production in the Shebele Valley in Somalia during the early 1980s.

Other Subject-Matter Areas

Additional research areas include pest management (weeds, stem borers and storage pests); agronomic practices (time of planting, plant population, intercropping); and the range of postharvest technologies. Considerable research has been undertaken in these areas during the past three decades and, although adoption and impacts have not been major in most countries to date, their importance is likely to grow in the future (Traxler and Byerlee 1991).

SUMMARY

Considerable progress has been made in developing a range of innovations that are collectively capable of sustaining further advances in maize production and productivity in a broad range of ecologies throughout the region. Most of the impacts to date have been associated with the adoption of the first generation of innovations, particularly improved germplasm which performed better even without major shifts in other production practices. This “low plum” is still not as fully utilized throughout the region as it might be. Yields are considerably below potential, and many farmers have not yet adopted the new varieties. Reforms in input delivery, peace, and the opening of isolated areas will assist in creating opportunities for farmers who have not yet had the option of using one or more new varieties to date. In addition, reforms and infrastructural improvements (roads and communications) in some countries may improve the chances for successful development of hybrid seed industries.

Research has increasingly turned its attention to the next generation of problems. There has been a diversification of themes and assessment criteria guiding germplasm improvement that better reflects the heterogeneity of farming systems and maize production in the region. Yield stability through pest and stress tolerance is receiving more attention. Nonbreeding themes, including soil fertility management, are the focus of increased efforts. Although progress will probably not be as dramatic as before, this will be at least partially offset by the improved targeting of research efforts that are taking place in response to FSR and other linkage activities.

Annex D

Statistical Tables

Annex D comprises tables of maize and other coarse grain cropped areas, production, and yields from 1966 to 1991 for the following:

Kenya	Tables D1–D4
Malawi	Table D5
Nigeria	Tables D6–D9
Senegal	Tables D10–D12
Zaire	Table D13
West Africa	Tables D14–D17
Central Africa	Table D18
East Africa	Tables D19–D22
Southern Africa	Tables D23–D26
Sub-Saharan Africa	Tables D27–D30

and tables of with and without technological change scenarios, five-year average for 1986–90, for:

Maize Production	Table D31
Coarse Grain Production	Table D32

SOURCES

Annual Crop Data

Area: Production, supply, and distribution spread sheets (PS&D) of the Foreign Agriculture Service (FAS) of the USDA; supplemented by data from the Food and Agriculture Organization (FAO) of the United Nations.

Production: Economic Research Service (ERS) of the USDA using PS&D spreadsheets and country statistical data with some revisions by ERS country analysts; supplemented by data from FAO.

Calories per Kg of Coarse Grain

FAO Food Composition Tables.

Agricultural Gross Domestic Product (AGDP)

World Tables 1991, The World Bank.

Value of Incremental Grain Production

Calculated from the 1990 U.S. Gulf port export price, as follows:

	US$/MT
FOB Gulf price	110
Average shipping and handling cost between Gulf and African port	40
Average CIF price, African port	150

Source: FAO *Food Outlook*, No. 12, Rome, December 1992.

FIVE-YEAR MOVING AVERAGES

The tables next to the annual crop data are a five-year moving average which has been calculated to reduce the effects of year-to-year fluctuations. Each five-year average annual figure is shown at the mid year.

SCENARIOS ASSUMING NO MAIZE RESEARCH

The tables include two estimates of annual crop production using different assumptions of cropped areas and yields in the absence of maize research. MARIA attempts to measure the part of production change that can be traced to research through comparing actual production with different scenarios expressing what might have existed without maize research. The key variables used in the "without research" scenarios are yield and the area devoted to maize cultivation. The scenarios take account of shifts in area to maize from other coarse grains, notably sorghum and millet.

Scenario I (Static yield) assumes that without maize research, the yield of maize would have remained at the 1966–70 five-year level. In this scenario, the area devoted to maize cultivation is allowed to expand as a constant proportion of the area actually put to coarse grains, including maize, sorghum, and millet. For example, if maize accounted for 50% of the total area planted to maize, sorghum, and millet during 1966–70, then it is assumed that the area planted to maize would continue to account for 50% of coarse grain area through to 1990. If technologies were absent, resource productivity and the attractiveness of maize production vis-à-vis other coarse grains would have remained unchanged.

Scenario II (Declining yield) takes account of the effects of pests, diseases, and declining soil fertility. Research has been responsible for incorporating tolerance to selected pests and diseases, such as maize streak virus, into improved germplasm, as well as providing a range of approaches for maintaining soil fertility. This scenario assumes that average yields would have fallen by 1% each year in the absence of these innovations. Sorghum and millet account for all expansion in the coarse grain area. In essence, Scenario II postulates that maize would progressively lose its competitive position compared to other coarse grains as a consequence of declining yields.

These scenarios represent two points in a range. While Scenario II is arguably on the pessimistic side, there is no basis to assume that declining yield is a less plausible assumption than simply no change in the absence of research-led innovation. Improvements in production brought about by farmer innovation also lie within this range.

ASSUMPTIONS FOR THE WITHOUT-MAIZE-RESEARCH TECHNOLOGY SCENARIOS

Scenario I (Static Yield)

(a) Maize yields remain same as 1966–70 annual average;
(b) Sorghum and millet yields are actual five-year annual averages;
(c) Total coarse grains areas are actual five-year annual averages;
(d) Maize area proportions of total coarse grains areas remain same as 1966–70 annual average.

Scenario II (Declining Yields)

(a) Maize yields decline by 1% per year;
(b) Sorghum and millet yields are actual five-year annual averages;
(c) Maize areas remain same as the 1966–70 annual average maize area;
(d) Total coarse grains areas are actual five-year annual averages.

Formulas for the Without-Maize-Research Technology Scenarios

Definitions

ZAi, ZYi, ZPi	=	Maize area, yield, and production in year i under Scenarios I and II;
MAi, MYi, MPi	=	Millet area, yield, and production in year i under Scenarios I and II;
SAi, SYi, SPi	=	Sorghum area, yield, and production in year i un-

der Scenarios I and II;

TAi, TYi, TPi = Total coarse grains area, yield, and production in year i under Scenarios I and II;

ZAai = Actual five-year average maize area at year i;

MYai = Actual five-year average millet yield at year i;

SYai = Actual five-year average sorghum yield at year i;

TAai = Actual five-year average area of total coarse grains at year i.

Scenario I formulas:

ZYi = $(ZY_{66} - ZY_{70})/5$

ZAi = $\frac{(ZA_{66} - ZA_{70})}{(TA_{66} - TA_{70})} \div TAai$

ZPi = ZYi x ZAi

MYi = MYai

MAi = (TAi - ZAi) x MAai/(TAai - ZAai)

MPi = MYi x MAi

SYi = SYai

SAi = (TAi - ZAi) x SAai / (TAai - ZAai)

SPi = SYi x SAi

TAi = ZAi + MAi + SAi

TPi = ZPi + MPi + SPi

TYi = TPi/TAi

Scenario II formulas:

ZYi = ZY(i - 1) x 0.9

ZAi = $(ZA_{66} - ZA_{70})/5$

ZPi = ZYi x ZAi

MYi = MYai

MAi = (TAi - ZAi) x MAi / (TAai - ZAai)

MPi = MYi x MAi

SYi = SYai

SAi = (TAi - ZAi) x SAai / (TAai - ZAai)

SPi = SYi x SAi

TAi = ZAi + MAi + SAi

TPi = ZPi + MPi + SPi

TYi = TPi/TAi

Table D.1. Kenya: Maize*

Year	--------Annual data--------			--5-year moving averages--			Scenario I ------(Static Yield)------			Scenario II ----(Declining Yield)----		
	Area 000 ha	Calc. yield mt/ha	Prod. 000 mt	Area 000 ha	Yield mt/ha	Prod. 000 mt	Area 000 ha	Yield mt/ha	Prod. 000 mt	Area 000 ha	Yield mt/ha	Prod. 000 mt
1966	1,214	1.20	1,451									
1967	1,170	1.40	1,633									
1968	1,214	1.32	1,600	1,221	1.24	1,517	1,221	1.24	1,517	1,221	1.24	1,517
1969	1,250	1.12	1,400	1,229	1.21	1,487	1,226	1.24	1,524	1,221	1.23	1,502
1970	1,255	1.20	1,500	1,245	1.21	1,500	1,239	1.24	1,539	1,221	1.22	1,487
1971	1,255	1.04	1,300	1,252	1.20	1,500	1,245	1.24	1,547	1,221	1.21	1,472
1972	1,250	1.36	1,700	1,252	1.23	1,540	1,247	1.24	1,549	1,221	1.19	1,457
1973	1,250	1.28	1,600	1,251	1.29	1,620	1,247	1.24	1,550	1,221	1.18	1,442
1974	1,250	1.28	1,600	1,250	1.44	1,799	1,248	1.24	1,551	1,221	1.17	1,428
1975	1,250	1.52	1,900	1,250	1.52	1,900	1,249	1.24	1,552	1,221	1.16	1,414
1976	1,250	1.76	2,195	1,230	1.59	1,959	1,234	1.24	1,534	1,221	1.15	1,400
1977	1,250	1.76	2,205	1,250	1.54	1,929	1,252	1.24	1,555	1,221	1.14	1,386
1978	1,150	1.65	1,895	1,298	1.46	1,899	1,291	1.24	1,605	1,221	1.12	1,372
1979	1,350	1.07	1,450	1,386	1.37	1,900	1,343	1.24	1,668	1,221	1.11	1,358
1980	1,488	1.18	1,750	1,480	1.30	1,927	1,394	1.24	1,732	1,221	1.10	1,344
1981	1,690	1.30	2,200	1,554	1.25	1,948	1,434	1.24	1,782	1,221	1.09	1,331
1982	1,720	1.36	2,340	1,604	1.25	1,998	1,457	1.24	1,811	1,221	1.08	1,318
1983	1,520	1.32	2,000	1,664	1.31	2,178	1,494	1.24	1,857	1,221	1.07	1,305
1984	1,600	1.06	1,700	1,685	1.37	2,303	1,520	1.24	1,889	1,221	1.06	1,291
1985	1,790	1.48	2,650	1,661	1.40	2,325	1,520	1.24	1,888	1,221	1.05	1,279
1986	1,795	1.57	2,825	1,717	1.45	2,497	1,579	1.24	1,963	1,221	1.04	1,266
1987	1,600	1.53	2,450	1,760	1.54	2,719	1,624	1.24	2,018	1,221	1.03	1,253
1988	1,800	1.59	2,860	1,768	1.56	2,757	1,636	1.24	2,033	1,221	1.02	1,241
1989	1,815	1.55	2,810									
1990	1,830	1.55	2,840									

* Annual data from USDA/ERS. See Introduction to Annex D for detailed explanation of scenario calculations.

Table D.2. Kenya: Millet*

Year	Annual data Area 000 ha	Annual data Calc. yield mt/ha	Annual data Prod. 000 mt	5-year moving averages Area 000 ha	5-year moving averages Yield mt/ha	5-year moving averages Prod. 000 mt	Scenario I (Static Yield) Area 000 ha	Scenario I (Static Yield) Yield mt/ha	Scenario I (Static Yield) Prod. 000 mt	Scenario II (Declining Yield) Area 000 ha	Scenario II (Declining Yield) Yield mt/ha	Scenario II (Declining Yield) Prod. 000 mt
1966	74	1.84	136									
1967	75	1.88	141									
1968	75	1.73	130	75	1.76	131	75	1.76	131	75	1.76	131
1969	75	1.60	120	75	1.73	130	76	1.73	131	77	1.73	134
1970	75	1.73	130	76	1.71	129	77	1.71	132	82	1.71	140
1971	76	1.71	130	76	1.71	130	78	1.71	133	85	1.71	145
1972	77	1.75	135	77	1.72	132	78	1.72	134	85	1.72	146
1973	77	1.75	135	77	1.70	131	78	1.70	133	86	1.70	145
1974	78	1.64	128	78	1.68	131	79	1.68	132	86	1.68	144
1975	78	1.64	128	79	1.65	130	79	1.65	130	87	1.65	143
1976	80	1.60	128	80	1.62	129	78	1.62	127	82	1.62	133
1977	81	1.60	130	80	1.56	125	80	1.56	124	88	1.56	138
1978	81	1.60	130	81	1.43	116	82	1.43	118	102	1.43	146
1979	81	1.36	110	81	1.25	100	94	1.25	117	131	1.25	163
1980	80	1.00	80	74	1.09	80	101	1.09	110	155	1.09	169
1981	80	0.65	52	67	0.90	60	105	0.90	95	174	0.90	157
1982	47	0.64	30	57	0.71	40	101	0.71	72	172	0.71	123
1983	47	0.64	30	52	0.70	36	103	0.70	72	185	0.70	130
1984	29	0.34	10	48	0.72	34	91	0.72	65	168	0.72	121
1985	56	1.07	60	60	0.69	41	102	0.69	70	189	0.69	130
1986	60	0.69	41	3	0.68	50	118	0.68	80	234	0.68	160
1987	110	0.60	66	86	0.69	60	136	0.69	94	284	0.69	196
1988	110	0.65	72	95	0.65	62	147	0.65	95	310	0.65	201
1989	96	0.63	60									
1990	100	0.70	70									

* Annual data from USDA/ERS. See Introduction to Annex D for detailed explanation of scenario calculations.

Table D.3. Kenya: Sorghum*

Year	Annual data: Area 000 ha	Annual data: Calc. yield mt/ha	Annual data: Prod. 000 mt	5-year moving averages: Area 000 ha	5-year moving averages: Yield mt/ha	5-year moving averages: Prod. 000 mt	Scenario I (Static Yield): Area 000 ha	Scenario I (Static Yield): Yield mt/ha	Scenario I (Static Yield): Prod. 000 mt	Scenario II (Declining Yield): Area 000 ha	Scenario II (Declining Yield): Yield mt/ha	Scenario II (Declining Yield): Prod. 000 mt
1966	210	1.10	231									
1967	210	1.14	239									
1968	205	1.07	220	205	1.09	223	205	1.09	223	205	1.09	223
1969	200	1.03	205	204	1.08	221	205	1.08	223	210	1.08	227
1970	201	1.09	220	203	1.08	219	207	1.08	224	220	1.08	238
1971	202	1.09	220	203	1.09	221	208	1.09	227	225	1.09	246
1972	205	1.12	230	204	1.10	224	208	1.10	228	227	1.10	249
1973	205	1.12	230	205	1.09	224	208	1.09	227	227	1.09	248
1974	206	1.06	219	206	1.09	224	208	1.09	226	228	1.09	247
1975	206	1.06	219	207	1.07	222	208	1.07	223	228	1.07	245
1976	209	1.07	223	208	1.06	220	205	1.06	217	215	1.06	228
1977	208	1.06	220	209	1.02	214	207	1.02	213	230	1.02	236
1978	210	1.05	221	209	1.00	210	214	1.00	215	265	1.00	266
1979	210	0.89	186	184	1.00	184	214	1.00	214	299	1.00	299
1980	210	0.95	200	160	0.95	151	219	0.95	207	338	0.95	319
1981	84	1.12	94	142	0.80	114	224	0.80	180	369	0.80	296
1982	87	0.64	56	131	0.74	97	234	0.74	172	399	0.74	293
1983	120	0.29	35	121	0.66	81	240	0.66	159	432	0.66	287
1984	155	0.63	98	136	0.63	86	258	0.63	163	480	0.63	303
1985	160	0.75	120	147	0.66	97	247	0.66	163	459	0.66	303
1986	160	0.76	122	152	0.78	119	245	0.78	192	487	0.78	382
1987	139	0.80	111	150	0.85	128	236	0.85	202	492	0.85	420
1988	144	1.00	144	148	0.89	132	228	0.89	204	481	0.89	429
1989	146	0.98	143									
1990	150	0.93	140									

* Annual data from USDA/ERS. See Introduction to Annex D for detailed explanation of scenario calculations.

Table D.4. Kenya: Maize, Millet, and Sorghum Total*

Year	--------Annual data--------			--5-year moving averages--			Scenario I ------(Static Yield)------			Scenario II ----(Declining Yield)----		
	Area 000 ha	Calc. yield mt/ha	Prod. 000 mt	Area 000 ha	Yield mt/ha	Prod. 000 mt	Area 000 ha	Yield mt/ha	Prod. 000 mt	Area 000 ha	Yield mt/ha	Prod. 000 mt
1966	1,498	1.21	1,818									
1967	1,455	1.38	2,013									
1968	1,494	1.31	1,950	1,501	1.25	1,871	1,501	1.25	1,871	1,501	1.25	1,871
1969	1,525	1.13	1,725	1,508	1.22	1,838	1,508	1.25	1,878	1,508	1.24	1,863
1970	1,531	1.21	1,850	1,523	1.21	1,848	1,523	1.24	1,895	1,523	1.22	1,865
1971	1,533	1.08	1,650	1,531	1.21	1,851	1,531	1.25	1,907	1,531	1.22	1,862
1972	1,532	1.35	2,065	1,532	1.24	1,895	1,532	1.25	1,911	1,532	1.21	1,852
1973	1,532	1.28	1,965	1,533	1.29	1,975	1,533	1.25	1,909	1,533	1.20	1,835
1974	1,534	1.27	1,947	1,534	1.40	2,154	1,534	1.24	1,908	1,534	1.19	1,820
1975	1,534	1.46	2,247	1,536	1.47	2,252	1,536	1.24	1,905	1,536	1.17	1,802
1976	1,539	1.65	2,546	1,517	1.52	2,308	1,517	1.24	1,878	1,517	1.16	1,760
1977	1,539	1.66	2,555	1,539	1.47	2,268	1,539	1.23	1,892	1,539	1.14	1,759
1978	1,441	1.56	2,246	1,588	1.40	2,225	1,588	1.22	1,937	1,588	1.12	1,784
1979	1,641	1.06	1,746	1,651	1.32	2,185	1,651	1.21	1,999	1,651	1.10	1,820
1980	1,778	1.14	2,030	1,714	1.26	2,159	1,714	1.20	2,049	1,714	1.07	1,833
1981	1,854	1.27	2,346	1,763	1.20	2,123	1,763	1.17	2,056	1,763	1.01	1,784
1982	1,854	1.31	2,426	1,791	1.19	2,135	1,791	1.15	2,054	1,791	0.97	1,734
1983	1,687	1.22	2,065	1,837	1.25	2,295	1,837	1.14	2,088	1,837	0.94	1,721
1984	1,784	1.01	1,808	1,869	1.30	2,423	1,869	1.13	2,117	1,869	0.92	1,715
1985	2,006	1.41	2,830	1,868	1.32	2,463	1,868	1.14	2,121	1,868	0.92	1,711
1986	2,015	1.48	2,988	1,942	1.37	2,666	1,942	1.15	2,235	1,942	0.93	1,807
1987	1,849	1.42	2,627	1,996	1.46	2,907	1,996	1.16	2,314	1,996	0.94	1,870
1988	2,054	1.50	3,076	2,011	1.47	2,951	2,011	1.16	2,332	2,011	0.93	1,871
1989	2,057	1.46	3,013									
1990	2,080	1.47	3,050									

* Annual data from USDA/ERS. See Introduction to Annex D for detailed explanation of scenario calculations.

Table D.5. Malawi: Maize*

	--------Annual data--------			--5-year moving averages--			Scenario I ------(Static Yield)------			Scenario II ----(Declining Yield)----		
Year	Area 000 ha	Calc. yield mt/ha	Prod. 000 mt	Area 000 ha	Yield mt/ha	Prod. 000 mt	Area 000 ha	Yield mt/ha	Prod. 000 mt	Area 000 ha	Yield mt/ha	Prod. 000 mt
1966	1,020	1.18	1,200									
1967	864	1.47	1,270									
1968	1,068	1.02	1,089	1,004	1.12	1,122	1,004	1.12	1,122	1,004	1.12	1,122
1969	1,068	1.08	1,153	1,010	1.09	1,102	1,010	1.12	1,129	1,010	1.11	1,118
1970	1,000	0.90	900	1,057	1.06	1,116	1,057	1.06	1,116	1,057	1.06	1,116
1971	1,050	1.05	1,100	1,074	1.06	1,139	1,074	1.06	1,133	1,074	1.05	1,122
1972	1,100	1.22	1,338	1,082	1.08	1,164	1,082	1.06	1,142	1,082	1.03	1,119
1973	1,150	1.05	1,202	1,082	1.09	1,184	1,082	1.06	1,142	1,082	1.02	1,108
1974	1,110	1.15	1,280	1,072	1.10	1,184	1,072	1.06	1,132	1,072	1.01	1,087
1975	1,000	1.00	1,000	1,052	1.10	1,156	1,052	1.06	1,111	1,052	1.00	1,056
1976	1,000	1.10	1,100	1,042	1.13	1,176	1,042	1.06	1,100	1,042	0.99	1,036
1977	1,000	1.20	1,200	1,020	1.14	1,160	1,020	1.06	1,077	1,020	0.98	1,004
1978	1,100	1.18	1,300	1,040	1.15	1,193	1,040	1.06	1,098	1,040	0.97	1,013
1979	1,000	1.20	1,200	1,060	1.15	1,222	1,060	1.06	1,119	1,060	0.96	1,022
1980	1,100	1.06	1,165	1,100	1.15	1,265	1,100	1.06	1,161	1,100	0.95	1,050
1981	1,100	1.13	1,245	1,120	1.14	1,279	1,120	1.06	1,182	1,120	0.95	1,059
1982	1,200	1.18	1,415	1,147	1.15	1,319	1,147	1.06	1,211	1,147	0.94	1,073
1983	1,200	1.14	1,370	1,156	1.17	1,357	1,156	1.06	1,220	1,156	0.93	1,071
1984	1,136	1.23	1,400	1,175	1.16	1,367	1,175	1.06	1,240	1,175	0.92	1,077
1985	1,144	1.18	1,355	1,171	1.13	1,329	1,171	1.06	1,236	1,171	0.91	1,063
1986	1,193	1.08	1,294	1,167	1.13	1,315	1,167	1.06	1,232	1,167	0.90	1,049
1987	1,182	1.04	1,225	1,194	1.12	1,337	1,194	1.06	1,260	1,194	0.89	1,062
1988	1,180	1.10	1,300	1,234	1.08	1,334	1,234	1.06	1,303	1,234	0.88	1,087
1989	1,271	1.19	1,510									
1990	1,344	1.00	1,343									

* Annual data from USDA/ERS. See Introduction to Annex D for detailed explanation of scenario calculations.

Table D.6. Nigeria: Maize*

Year	--------Annual data-------- Area 000 ha	Calc. yield mt/ha	Prod. 000 mt	--5-year moving averages-- Area 000 ha	Yield mt/ha	Prod. 000 mt	Scenario I ------(Static Yield)------ Area 000 ha	Yield mt/ha	Prod. 000 mt	Scenario II ----(Declining Yield)---- Area 000 ha	Yield mt/ha	Prod. 000 mt
1966	1,244	0.82	1,020									
1967	1,333	0.75	1,000									
1968	826	1.15	950	1,207	0.95	1,141	1,207	0.95	1,141	1,207	0.95	1,141
1969	1,371	1.04	1,426	1,240	0.92	1,146	1,250	0.95	1,182	1,207	0.94	1,130
1970	1,260	1.04	1,310	1,259	0.94	1,182	1,279	0.95	1,210	1,207	0.93	1,118
1971	1,410	0.74	1,042	1,405	0.89	1,249	1,299	0.95	1,229	1,207	0.92	1,107
1972	1,426	0.83	1,182	1,456	0.85	1,234	1,306	0.95	1,235	1,207	0.91	1,096
1973	1,560	0.83	1,287	1,539	0.81	1,252	1,320	0.95	1,248	1,207	0.90	1,084
1974	1,625	0.83	1,350	1,602	0.83	1,332	1,328	0.95	1,256	1,207	0.89	1,073
1975	1,675	0.84	1,400	1,677	0.83	1,395	1,350	0.95	1,276	1,207	0.88	1,061
1976	1,725	0.83	1,440	1,729	0.85	1,466	1,382	0.95	1,307	1,207	0.87	1,050
1977	1,800	0.83	1,500	1,774	0.86	1,530	1,397	0.95	1,321	1,207	0.86	1,038
1978	1,820	0.90	1,640	1,819	0.88	1,594	1,407	0.95	1,330	1,207	0.85	1,027
1979	1,850	0.90	1,670	1,862	0.89	1,656	1,418	0.95	1,341	1,207	0.84	1,016
1980	1,900	0.91	1,720	1,896	0.90	1,713	1,425	0.95	1,348	1,207	0.83	1,004
1981	1,940	0.90	1,750	1,910	0.90	1,717	1,404	0.95	1,328	1,207	0.82	993
1982	1,970	0.91	1,785	1,935	0.90	1,743	1,407	0.95	1,330	1,207	0.81	981
1983	1,890	0.88	1,660	1,955	0.92	1,799	1,375	0.95	1,300	1,207	0.80	970
1984	1,975	0.91	1,800	1,967	0.94	1,849	1,314	0.95	1,243	1,207	0.79	959
1985	2,000	1.00	2,000	1,973	0.95	1,872	1,234	0.95	1,167	1,207	0.78	947
1986	2,000	1.00	2,000	2,035	0.97	1,980	1,195	0.95	1,130	1,207	0.78	936
1987	2,000	0.95	1,900	2,040	0.98	2,000	1,127	0.95	1,066	1,207	0.77	924
1988	2,200	1.00	2,200	2,000	0.95	1,904	1,087	0.95	1,028	1,207	0.76	917
1989	2,000	0.95	1,900									
1990	1,800	0.84	1,520									

* Annual data from USDA/ERS. See Introduction to Annex D for detailed explanation of scenario calculations.

Table D.7. Nigeria: Millet*

	--------Annual data--------			--5-year moving averages--			Scenario I ------(Static Yield)------			Scenario II ----(Declining Yield)----		
Year	Area 000 ha	Calc. yield mt/ha	Prod. 000 mt	Area 000 ha	Yield mt/ha	Prod. 000 mt	Area 000 ha	Yield mt/ha	Prod. 000 mt	Area 000 ha	Yield mt/ha	Prod. 000 mt
1966	4,050	0.43	1,744									
1967	4,369	0.59	2,585									
1968	4,462	0.49	2,190	4,535	0.53	2,390	4,535	0.53	2,390	4,535	0.53	2,390
1969	4,866	0.55	2,667	4,780	0.55	2,630	4,775	0.55	2,628	4,795	0.55	2,639
1970	4,926	0.56	2,763	4,874	0.56	2,723	4,864	0.56	2,717	4,898	0.56	2,736
1971	5,275	0.56	2,946	4,881	0.56	2,715	4,931	0.56	2,743	4,975	0.56	2,767
1972	4,839	0.63	3,048	4,888	0.56	2,741	4,959	0.56	2,781	5,005	0.56	2,807
1973	4,500	0.48	2,150	4,906	0.56	2,762	5,009	0.56	2,820	5,062	0.56	2,850
1974	4,900	0.57	2,800	4,811	0.57	2,746	4,937	0.57	2,818	4,993	0.57	2,850
1975	5,015	0.57	2,865	4,827	0.56	2,726	4,977	0.56	2,810	5,042	0.56	2,847
1976	4,800	0.60	2,865	4,927	0.59	2,916	5,085	0.59	3,010	5,165	0.59	3,057
1977	4,920	0.60	2,950	4,947	0.60	2,984	5,118	0.60	3,087	5,205	0.60	3,139
1978	5,000	0.62	3,100	4,950	0.61	3,037	5,137	0.61	3,151	5,227	0.61	3,207
1979	5,000	0.63	3,140	4,996	0.62	3,100	5,198	0.62	3,225	5,294	0.62	3,285
1980	5,030	0.62	3,130	5,022	0.62	3,129	5,236	0.62	3,263	5,336	0.62	3,325
1981	5,030	0.63	3,180	4,836	0.61	2,969	5,062	0.61	3,108	5,150	0.61	3,162
1982	5,050	0.61	3,095	4,836	0.62	2,981	5,072	0.62	3,127	5,161	0.62	3,182
1983	4,070	0.57	2,300	4,850	0.60	2,915	5,117	0.60	3,076	5,195	0.60	3,122
1984	5,000	0.64	3,200	4,584	0.63	2,869	4,885	0.63	3,057	4,934	0.63	3,088
1985	5,100	0.55	2,800	4,194	0.63	2,650	4,531	0.63	2,863	4,543	0.63	2,870
1986	3,700	0.80	2,950	4,080	0.67	2,750	4,470	0.67	3,013	4,464	0.67	3,009
1987	3,100	0.65	2,000	3,780	0.70	2,650	4,202	0.70	2,946	4,165	0.70	2,920
1988	3,500	0.80	2,800	3,460	0.73	2,522	3,862	0.73	2,815	3,809	0.73	2,777
1989	3,500	0.77	2,700									
1990	3,500	0.62	2,160									

* Annual data from USDA/ERS. See Introduction to Annex D for detailed explanation of scenario calculations.

Table D.8. Nigeria: Sorghum*

Year	--------Annual data--------			--5-year moving averages--			Scenario I ------(Static Yield)------			Scenario II ----(Declining Yield)----		
	Area 000 ha	Calc. yield mt/ha	Prod. 000 mt	Area 000 ha	Yield mt/ha	Prod. 000 mt	Area 000 ha	Yield mt/ha	Prod. 000 mt	Area 000 ha	Yield mt/ha	Prod. 000 mt
1966	4,826	0.65	3,154									
1967	4,719	0.72	3,382									
1968	5,159	0.55	2,843	5,202	0.66	3,427	5,202	0.66	3,427	5,202	0.66	3,427
1969	5,638	0.70	3,941	5,319	0.64	3,424	5,314	0.64	3,421	5,336	0.64	3,436
1970	5,670	0.67	3,816	5,470	0.63	3,460	5,459	0.63	3,453	5,497	0.63	3,478
1971	5,409	0.58	3,140	5,498	0.63	3,485	5,554	0.63	3,521	5,603	0.63	3,552
1972	5,472	0.65	3,561	5,499	0.62	3,397	5,579	0.62	3,446	5,631	0.62	3,479
1973	5,300	0.56	2,968	5,524	0.61	3,352	5,640	0.61	3,422	5,700	0.61	3,459
1974	5,645	0.62	3,500	5,630	0.61	3,460	5,778	0.61	3,551	5,844	0.61	3,591
1975	5,795	0.62	3,590	5,736	0.61	3,498	5,914	0.61	3,606	5,991	0.61	3,653
1976	5,940	0.62	3,680	5,876	0.62	3,656	6,065	0.62	3,773	6,160	0.62	3,833
1977	6,000	0.63	3,750	5,947	0.62	3,713	6,153	0.62	3,842	6,257	0.62	3,906
1978	6,000	0.63	3,760	5,988	0.63	3,755	6,214	0.63	3,897	6,323	0.63	3,965
1979	6,000	0.63	3,785	6,000	0.63	3,759	6,242	0.63	3,911	6,358	0.63	3,983
1980	6,000	0.63	3,800	6,005	0.64	3,836	6,261	0.64	4,000	6,380	0.64	4,076
1981	6,000	0.62	3,700	5,985	0.60	3,616	6,265	0.60	3,785	6,374	0.60	3,851
1982	6,025	0.69	4,134	5,985	0.60	3,597	6,277	0.60	3,772	6,388	0.60	3,839
1983	5,900	0.45	2,660	5,665	0.62	3,537	5,977	0.62	3,732	6,068	0.62	3,788
1984	6,000	0.62	3,690	5,365	0.66	3,517	5,717	0.66	3,748	5,775	0.66	3,786
1985	4,400	0.80	3,500	5,020	0.65	3,270	5,423	0.65	3,532	5,437	0.65	3,542
1986	4,500	0.80	3,600	4,720	0.73	3,438	5,171	0.73	3,766	5,164	0.73	3,762
1987	4,300	0.67	2,900	4,400	0.77	3,400	4,891	0.77	3,779	4,848	0.77	3,746
1988	4,400	0.80	3,500	4,400	0.74	3,260	4,911	0.74	3,639	4,844	0.74	3,589
1989	4,400	0.80	3,500									
1990	4,400	0.64	2,800									

* Annual data from USDA/ERS. See Introduction to Annex D for detailed explanation of scenario calculations.

Table D.9. Nigeria: Maize, Millet, and Sorghum Total*

	--------Annual data--------			--5-year moving averages--			Scenario I ------(Static Yield)------			Scenario II ----(Declining Yield)----		
Year	Area 000 ha	Calc. yield mt/ha	Prod. 000 mt	Area 000 ha	Yield mt/ha	Prod. 000 mt	Area 000 ha	Yield mt/ha	Prod. 000 mt	Area 000 ha	Yield mt/ha	Prod. 000 mt
1966	10,120	0.58	5,918									
1967	10,421	0.67	6,967									
1968	10,447	0.57	5,983	10,944	0.64	6,958	10,944	0.64	6,958	10,944	0.64	6,958
1969	11,875	0.68	8,034	11,339	0.64	7,200	11,339	0.64	7,231	11,339	0.64	7,204
1970	11,856	0.67	7,889	11,602	0.63	7,365	11,602	0.64	7,380	11,602	0.63	7,332
1971	12,094	0.59	7,128	11,784	0.63	7,449	11,784	0.64	7,492	11,784	0.63	7,426
1972	11,737	0.66	7,791	11,843	0.62	7,373	11,843	0.63	7,462	11,843	0.62	7,381
1973	11,360	0.56	6,405	11,969	0.62	7,366	11,969	0.63	7,490	11,969	0.62	7,393
1974	12,170	0.63	7,650	12,043	0.63	7,537	12,043	0.63	7,624	12,043	0.62	7,513
1975	12,485	0.63	7,855	12,240	0.62	7,619	12,240	0.63	7,693	12,240	0.62	7,562
1976	12,465	0.64	7,985	12,532	0.64	8,038	12,532	0.65	8,090	12,532	0.63	7,940
1977	12,720	0.64	8,200	12,668	0.65	8,227	12,668	0.65	8,250	12,668	0.64	8,084
1978	12,820	0.66	8,500	12,757	0.66	8,386	12,757	0.66	8,378	12,757	0.64	8,199
1979	12,850	0.67	8,595	12,858	0.66	8,515	12,858	0.66	8,477	12,858	0.64	8,283
1980	12,930	0.67	8,650	12,923	0.67	8,678	12,923	0.67	8,610	12,923	0.65	8,404
1981	12,970	0.67	8,630	12,731	0.65	8,302	12,731	0.65	8,220	12,731	0.63	8,006
1982	13,045	0.69	9,014	12,756	0.65	8,321	12,756	0.65	8,229	12,756	0.63	8,002
1983	11,860	0.56	6,620	12,470	0.66	8,251	12,470	0.65	8,108	12,470	0.63	7,881
1984	12,975	0.67	8,690	11,916	0.69	8,235	11,916	0.68	8,048	11,916	0.66	7,832
1985	11,500	0.72	8,300	11,187	0.70	7,792	11,187	0.68	7,562	11,187	0.66	7,359
1986	10,200	0.84	8,550	10,835	0.75	8,168	10,835	0.73	7,909	10,835	0.71	7,706
1987	9,400	0.72	6,800	10,220	0.79	8,050	10,220	0.76	7,791	10,220	0.74	7,591
1988	10,100	0.84	8,500	9,860	0.78	7,686	9,860	0.76	7,482	9,860	0.74	7,283
1989	9,900	0.82	8,100									
1990	9,700	0.67	6,480									

* Annual data from USDA/ERS. See Introduction to Annex D for detailed explanation of scenario calculations.

Table D.10. Senegal: Maize*

	--------Annual data--------			--5-year moving averages--			Scenario I ------(Static Yield)------			Scenario II ----(Declining Yield)----		
Year	Area 000 ha	Calc. yield mt/ha	Prod. 000 mt	Area 000 ha	Yield mt/ha	Prod. 000 mt	Area 000 ha	Yield mt/ha	Prod. 000 mt	Area 000 ha	Yield mt/ha	Prod. 000 mt
1966	54	0.78	42									
1967	72	0.79	57									
1968	36	0.69	25	54	0.77	41	54	0.77	41	54	0.77	41
1969	55	0.89	49	53	0.77	40	53	0.77	41	54	0.76	41
1970	51	0.65	33	45	0.74	33	51	0.77	39	54	0.75	40
1971	49	0.78	38	45	0.77	35	51	0.77	39	54	0.75	40
1972	32	0.63	20	44	0.76	34	52	0.77	40	54	0.74	40
1973	39	0.87	34	44	0.82	36	52	0.77	40	54	0.73	39
1974	49	0.88	43	44	0.84	37	52	0.77	40	54	0.72	39
1975	50	0.88	44	48	0.82	40	52	0.77	40	54	0.71	38
1976	49	0.90	44	52	0.84	44	52	0.77	40	54	0.71	38
1977	54	0.61	33	55	0.80	44	50	0.77	39	54	0.70	37
1978	56	0.96	54	61	0.77	47	52	0.77	40	54	0.69	37
1979	68	0.68	46	62	0.83	52	55	0.77	42	54	0.68	37
1980	78	0.73	57	69	0.89	61	55	0.77	43	54	0.68	36
1981	56	1.21	68	72	0.87	63	53	0.77	41	54	0.67	36
1982	86	0.95	82	75	0.98	73	53	0.77	41	54	0.66	35
1983	71	0.86	61	81	1.12	91	56	0.77	43	54	0.65	35
1984	83	1.19	99	89	1.11	99	54	0.77	42	54	0.65	35
1985	111	1.32	147	92	1.15	106	55	0.77	42	54	0.64	34
1986	95	1.14	108	100	1.19	118	58	0.77	45	54	0.63	34
1987	99	1.15	114	105	1.17	123	59	0.77	45	54	0.62	33
1988	110	1.12	123	106	1.16	123	57	0.77	44	54	0.61	33
1989	112	1.11	125									
1990	114	1.28	146									

* Annual data from USDA/ERS. See Introduction to Annex D for detailed explanation of scenario calculations.

Table D.11. Senegal: Millet and Sorghum*

	--------Annual data--------			--5-year moving averages--			Scenario I ------(Static Yield)------			Scenario II ----(Declining Yield)----		
Year	Area 000 ha	Calc. yield mt/ha	Prod. 000 mt	Area 000 ha	Yield mt/ha	Prod. 000 mt	Area 000 ha	Yield mt/ha	Prod. 000 mt	Area 000 ha	Yield mt/ha	Prod. 000 mt
1966	997	0.43	424									
1967	1,156	0.57	655									
1968	1,054	0.43	450	1,042	0.49	513	1,042	0.49	513	1,042	0.49	513
1969	1,037	0.61	635	1,037	0.53	545	1,036	0.53	544	1,036	0.53	544
1970	967	0.41	401	993	0.48	478	987	0.48	475	984	0.48	474
1971	970	0.60	583	1,003	0.49	491	997	0.49	488	994	0.49	486
1972	936	0.35	323	1,024	0.51	523	1,016	0.51	518	1,015	0.51	518
1973	1,103	0.46	511	1,024	0.55	567	1,015	0.55	562	1,014	0.55	561
1974	1,145	0.69	795	1,020	0.55	562	1,011	0.55	557	1,010	0.55	556
1975	965	0.64	621	1,021	0.57	581	1,017	0.57	579	1,016	0.57	578
1976	949	0.59	558	1,011	0.63	639	1,011	0.63	639	1,009	0.63	638
1977	943	0.45	420	976	0.60	585	981	0.60	588	978	0.60	586
1978	1,055	0.76	803	1,006	0.57	571	1,015	0.57	576	1,014	0.57	575
1979	968	0.54	521	1,052	0.58	607	1,060	0.58	611	1,061	0.58	612
1980	1,117	0.50	553	1,062	0.60	640	1,075	0.60	648	1,077	0.60	649
1981	1,177	0.63	736	1,007	0.55	549	1,026	0.55	560	1,026	0.55	559
1982	991	0.59	585	1,014	0.53	539	1,036	0.53	551	1,035	0.53	551
1983	784	0.45	352	1,058	0.58	619	1,083	0.58	634	1,086	0.58	635
1984	1,002	0.47	471	1,021	0.59	598	1,056	0.59	619	1,057	0.59	619
1985	1,335	0.71	950	1,038	0.62	642	1,074	0.62	664	1,076	0.62	665
1986	993	0.64	634	1,085	0.64	690	1,127	0.64	717	1,131	0.64	719
1987	1,074	0.75	801	1,102	0.68	747	1,148	0.68	778	1,154	0.68	782
1988	1,023	0.58	595	1,052	0.66	690	1,102	0.66	722	1,105	0.66	724
1989	1,085	0.69	753									
1990	1,086	0.61	666									

* Annual data from USDA/ERS. See Introduction to Annex D for detailed explanation of scenario calculations.

Table D.12. Senegal: Maize, Millet, and Sorghum Total*

Year	--------Annual data--------			--5-year moving averages--			Scenario I ------(Static Yield)------			Scenario II ----(Declining Yield)----		
	Area 000 ha	Calc. yield mt/ha	Prod. 000 mt	Area 000 ha	Yield mt/ha	Prod. 000 mt	Area 000 ha	Yield mt/ha	Prod. 000 mt	Area 000 ha	Yield mt/ha	Prod. 000 mt
1966	1,051	0.44	466									
1967	1,228	0.58	712									
1968	1,090	0.44	475	1,096	0.51	554	1,096	0.51	554	1,096	0.51	554
1969	1,092	0.63	684	1,089	0.54	585	1,089	0.54	585	1,089	0.54	585
1970	1,018	0.43	434	1,037	0.49	511	1,037	0.50	514	1,037	0.50	514
1971	1,019	0.61	621	1,048	0.50	525	1,048	0.50	527	1,048	0.50	526
1972	968	0.35	343	1,068	0.52	556	1,068	0.52	559	1,068	0.52	557
1973	1,142	0.48	545	1,068	0.56	602	1,068	0.56	602	1,068	0.56	600
1974	1,194	0.70	838	1,063	0.56	599	1,063	0.56	597	1,063	0.56	595
1975	1,015	0.66	665	1,069	0.58	621	1,069	0.58	619	1,069	0.58	616
1976	998	0.60	602	1,063	0.64	683	1,063	0.64	679	1,063	0.64	676
1977	997	0.45	453	1,031	0.61	629	1,031	0.61	626	1,031	0.60	623
1978	1,111	0.77	857	1,067	0.58	618	1,067	0.58	616	1,067	0.57	612
1979	1,036	0.55	567	1,114	0.59	658	1,114	0.59	653	1,114	0.58	648
1980	1,195	0.51	610	1,130	0.62	701	1,130	0.61	690	1,130	0.61	685
1981	1,233	0.65	804	1,079	0.57	612	1,079	0.56	600	1,079	0.55	595
1982	1,077	0.62	667	1,089	0.56	613	1,089	0.54	592	1,089	0.54	586
1983	855	0.48	413	1,139	0.62	710	1,139	0.59	677	1,139	0.59	670
1984	1,085	0.53	570	1,110	0.63	698	1,110	0.60	661	1,110	0.59	654
1985	1,446	0.76	1,097	1,129	0.66	747	1,129	0.63	707	1,129	0.62	699
1986	1,088	0.68	742	1,185	0.68	808	1,185	0.64	761	1,185	0.64	753
1987	1,173	0.78	915	1,207	0.72	870	1,207	0.68	823	1,207	0.68	815
1988	1,133	0.63	718	1,158	0.70	813	1,158	0.66	766	1,158	0.65	757
1989	1,197	0.73	878									
1990	1,200	0.68	811									

* Annual data from USDA/ERS. See Introduction to Annex D for detailed explanation of scenario calculations.

Table D.13. Zaire: Maize*

Year	--------Annual data--------			--5-year moving averages--			Scenario I ------(Static Yield)------			Scenario II ----(Declining Yield)----		
	Area 000 ha	Calc. yield mt/ha	Prod. 000 mt	Area 000 ha	Yield mt/ha	Prod. 000 mt	Area 000 ha	Yield mt/ha	Prod. 000 mt	Area 000 ha	Yield mt/ha	Prod. 000 mt
1966	540	0.50	270									
1967	555	0.54	297									
1968	570	0.44	250	569	0.56	319	569	0.56	319	569	0.56	319
1969	582	0.60	350	582	0.60	352	581	0.56	326	569	0.56	316
1970	596	0.72	428	595	0.64	383	597	0.56	335	569	0.55	313
1971	608	0.72	436	607	0.70	425	612	0.56	344	569	0.54	309
1972	617	0.73	452	622	0.72	450	630	0.56	353	569	0.54	306
1973	634	0.72	459	638	0.73	464	645	0.56	362	569	0.53	303
1974	656	0.73	477	655	0.73	478	662	0.56	371	569	0.53	300
1975	675	0.73	495	672	0.73	490	678	0.56	381	569	0.52	297
1976	692	0.74	510	687	0.73	498	691	0.56	388	569	0.52	293
1977	705	0.72	510	701	0.74	521	704	0.56	395	569	0.51	290
1978	706	0.71	500	715	0.76	541	714	0.56	400	569	0.50	287
1979	728	0.81	592	727	0.78	567	726	0.56	407	569	0.50	284
1980	743	0.80	594	742	0.81	598	742	0.56	416	569	0.49	281
1981	751	0.85	639	760	0.83	633	760	0.56	427	569	0.49	278
1982	784	0.85	666	780	0.84	655	783	0.56	439	569	0.48	274
1983	792	0.85	673	801	0.85	682	807	0.56	453	569	0.48	271
1984	831	0.85	704	824	0.85	700	830	0.56	466	569	0.47	268
1985	849	0.86	726	842	0.85	712	852	0.56	478	569	0.47	265
1986	866	0.84	728	859	0.84	724	873	0.56	490	569	0.46	262
1987	874	0.84	730	868	0.85	741	886	0.56	497	569	0.45	258
1988	874	0.84	730	873	0.86	750	895	0.56	502	569	0.45	256
1989	875	0.90	790									
1990	875	0.88	770									

* Annual data from USDA/ERS. See Introduction to Annex D for detailed explanation of scenario calculations.

Table D.14. West Africa: Maize*

Year	Annual data: Area 000 ha	Annual data: Calc. yield mt/ha	Annual data: Prod. 000 mt	5-year moving averages: Area 000 ha	5-year moving averages: Yield mt/ha	5-year moving averages: Prod. 000 mt	Scenario I (Static Yield): Area 000 ha	Scenario I (Static Yield): Yield mt/ha	Scenario I (Static Yield): Prod. 000 mt	Scenario II (Declining Yield): Area 000 ha	Scenario II (Declining Yield): Yield mt/ha	Scenario II (Declining Yield): Prod. 000 mt
1966	2,764	0.84	2,318									
1967	3,000	0.80	2,386									
1968	2,390	0.93	2,227	2,766	0.89	2,461	2,766	0.89	2,461	2,766	0.89	2,461
1969	2,825	0.95	2,694	2,789	0.89	2,482	2,830	0.89	2,519	2,766	0.88	2,437
1970	2,850	0.94	2,683	2,755	0.90	2,485	2,848	0.89	2,535	2,766	0.87	2,412
1971	2,881	0.84	2,422	2,876	0.89	2,563	2,873	0.89	2,557	2,766	0.86	2,388
1972	2,828	0.85	2,400	2,925	0.88	2,587	2,880	0.89	2,563	2,766	0.85	2,363
1973	2,997	0.87	2,617	2,994	0.87	2,604	2,884	0.89	2,566	2,766	0.85	2,338
1974	3,068	0.92	2,813	3,060	0.87	2,647	2,910	0.89	2,590	2,766	0.84	2,314
1975	3,198	0.87	2,768	3,161	0.86	2,734	2,976	0.89	2,649	2,766	0.83	2,289
1976	3,211	0.82	2,640	3,251	0.87	2,844	3,049	0.89	2,713	2,766	0.82	2,265
1977	3,330	0.85	2,834	3,346	0.87	2,919	3,081	0.89	2,742	2,766	0.81	2,240
1978	3,450	0.92	3,164	3,420	0.88	3,009	3,128	0.89	2,784	2,766	0.80	2,215
1979	3,542	0.90	3,188	3,524	0.89	3,145	3,178	0.89	2,828	2,766	0.79	2,191
1980	3,568	0.90	3,218	3,609	0.90	3,246	3,217	0.89	2,863	2,766	0.78	2,166
1981	3,728	0.89	3,322	3,685	0.88	3,226	3,228	0.89	2,873	2,766	0.77	2,141
1982	3,755	0.89	3,340	3,870	0.87	3,373	3,286	0.89	2,925	2,766	0.77	2,117
1983	3,830	0.80	3,061	3,999	0.89	3,541	3,304	0.89	2,941	2,766	0.76	2,092
1984	4,471	0.88	3,924	4,116	0.90	3,698	3,268	0.89	2,909	2,766	0.75	2,068
1985	4,211	0.96	4,060	4,221	0.90	3,812	3,198	0.89	2,846	2,766	0.74	2,043
1986	4,315	0.95	4,104	4,426	0.94	4,153	3,235	0.89	2,879	2,766	0.73	2,018
1987	4,280	0.91	3,909	4,468	0.96	4,300	3,210	0.89	2,857	2,766	0.72	1,994
1988	4,853	0.98	4,768	4,492	0.95	4,274	3,174	0.89	2,824	2,766	0.71	1,964
1989	4,679	1.00	4,658	4,559	0.97	4,401	3,211	0.89	2,857	2,766	0.70	1,936
1990	4,334	0.91	3,932									
1991	4,650	1.02	4,738									

* Annual data from USDA/ERS. See Introduction to Annex D for detailed explanation of scenario calculations.

Table D.15. West Africa: Millet*

Year	Annual data: Area 000 ha	Annual data: Calc. yield mt/ha	Annual data: Prod. 000 mt	5-year moving averages: Area 000 ha	5-year moving averages: Yield mt/ha	5-year moving averages: Prod. 000 mt	Scenario I (Static Yield): Area 000 ha	Scenario I (Static Yield): Yield mt/ha	Scenario I (Static Yield): Prod. 000 mt	Scenario II (Declining Yield): Area 000 ha	Scenario II (Declining Yield): Yield mt/ha	Scenario II (Declining Yield): Prod. 000 mt
1966	9,655	0.48	4,644									
1967	10,129	0.58	5,880									
1968	10,118	0.50	5,033	10,421	0.53	5,483	10,421	0.53	5,483	10,421	0.53	5,483
1969	11,168	0.56	6,218	10,737	0.54	5,747	10,713	0.54	5,734	10,751	0.54	5,755
1970	11,034	0.51	5,643	10,790	0.53	5,698	10,734	0.53	5,669	10,783	0.53	5,695
1971	11,238	0.53	5,963	10,784	0.52	5,621	10,786	0.52	5,622	10,849	0.52	5,655
1972	10,393	0.54	5,634	10,755	0.52	5,605	10,781	0.52	5,618	10,848	0.52	5,653
1973	10,088	0.46	4,646	10,641	0.53	5,640	10,706	0.53	5,674	10,775	0.53	5,711
1974	11,021	0.56	6,138	10,642	0.53	5,657	10,729	0.53	5,703	10,813	0.53	5,748
1975	10,468	0.56	5,818	10,888	0.53	5,736	10,996	0.53	5,793	11,118	0.53	5,858
1976	11,240	0.54	6,048	11,117	0.55	6,151	11,235	0.55	6,216	11,399	0.55	6,307
1977	11,625	0.52	6,032	11,185	0.56	6,222	11,339	0.56	6,308	11,522	0.56	6,409
1978	11,233	0.60	6,720	11,448	0.56	6,370	11,619	0.56	6,465	11,831	0.56	6,583
1979	11,361	0.57	6,491	11,620	0.57	6,578	11,823	0.57	6,693	12,064	0.57	6,830
1980	11,781	0.56	6,559	11,728	0.58	6,753	11,957	0.58	6,885	12,222	0.58	7,038
1981	12,099	0.59	7,089	11,687	0.56	6,579	11,953	0.56	6,728	12,223	0.56	6,880
1982	12,166	0.57	6,907	11,842	0.55	6,536	12,183	0.55	6,724	12,487	0.55	6,892
1983	11,028	0.53	5,847	12,071	0.56	6,749	12,484	0.56	6,980	12,805	0.56	7,159
1984	12,134	0.52	6,276	11,945	0.57	6,849	12,454	0.57	7,141	12,756	0.57	7,314
1985	12,926	0.59	7,625	11,613	0.58	6,721	12,230	0.58	7,078	12,490	0.58	7,229
1986	11,469	0.66	7,592	11,851	0.61	7,215	12,582	0.61	7,660	12,869	0.61	7,835
1987	10,509	0.60	6,267	11,860	0.63	7,517	12,640	0.63	8,011	12,916	0.63	8,186
1988	12,219	0.68	8,315	11,529	0.63	7,270	12,337	0.63	7,779	12,586	0.63	7,937
1989	12,176	0.64	7,786	11,656	0.63	7,386	12,482	0.63	7,909	12,755	0.63	8,082
1990	11,271	0.57	6,390									
1991	12,106	0.67	8,171									

* Annual data from USDA/ERS. See Introduction to Annex D for detailed explanation of scenario calculations.

Table D.16. West Africa: Sorghum*

Year	--------Annual data--------			--5-year moving averages--			Scenario I ------(Static Yield)------			Scenario II ----(Declining Yield)----		
	Area 000 ha	Calc. yield mt/ha	Prod. 000 mt	Area 000 ha	Yield mt/ha	Prod. 000 mt	Area 000 ha	Yield mt/ha	Prod. 000 mt	Area 000 ha	Yield mt/ha	Prod. 000 mt
1966	6,687	0.62	4,142									
1967	6,840	0.66	4,502									
1968	6,828	0.55	3,744	7,128	0.62	4,436	7,128	0.62	4,436	7,128	0.62	4,436
1969	7,620	0.65	4,939	7,260	0.61	4,431	7,244	0.61	4,421	7,270	0.61	4,437
1970	7,663	0.63	4,853	7,375	0.60	4,431	7,337	0.60	4,408	7,371	0.60	4,428
1971	7,349	0.56	4,119	7,441	0.60	4,449	7,442	0.60	4,450	7,486	0.60	4,476
1972	7,416	0.61	4,499	7,473	0.59	4,401	7,491	0.59	4,412	7,538	0.59	4,439
1973	7,154	0.54	3,837	7,545	0.58	4,388	7,590	0.58	4,415	7,639	0.58	4,443
1974	7,780	0.60	4,697	7,670	0.59	4,524	7,733	0.59	4,561	7,794	0.59	4,597
1975	8,023	0.60	4,788	7,811	0.59	4,615	7,888	0.59	4,660	7,976	0.59	4,712
1976	7,978	0.60	4,798	8,022	0.60	4,844	8,107	0.60	4,895	8,226	0.60	4,967
1977	8,120	0.61	4,953	8,098	0.61	4,910	8,209	0.61	4,977	8,342	0.61	5,057
1978	8,211	0.61	4,982	8,107	0.61	4,942	8,229	0.61	5,016	8,379	0.61	5,108
1979	8,157	0.62	5,026	8,198	0.61	4,970	8,341	0.61	5,056	8,511	0.61	5,160
1980	8,072	0.61	4,953	8,293	0.61	5,042	8,455	0.61	5,140	8,642	0.61	5,254
1981	8,430	0.59	4,934	8,339	0.58	4,808	8,529	0.58	4,918	8,722	0.58	5,029
1982	8,597	0.62	5,314	8,425	0.57	4,765	8,668	0.57	4,903	8,884	0.57	5,025
1983	8,442	0.45	3,813	8,200	0.58	4,759	8,481	0.58	4,922	8,698	0.58	5,049
1984	8,586	0.56	4,813	7,943	0.61	4,817	8,282	0.61	5,023	8,483	0.61	5,145
1985	6,944	0.71	4,921	7,656	0.61	4,632	8,062	0.61	4,878	8,234	0.61	4,982
1986	7,149	0.73	5,226	7,481	0.66	4,942	7,942	0.66	5,247	8,124	0.66	5,367
1987	7,158	0.61	4,388	7,252	0.70	5,041	7,729	0.70	5,372	7,898	0.70	5,490
1988	7,570	0.71	5,364	7,288	0.68	4,938	7,798	0.68	5,284	7,956	0.68	5,391
1989	7,440	0.71	5,306	7,367	0.68	4,975	7,889	0.68	5,327	8,061	0.68	5,444
1990	7,122	0.62	4,409									
1991	7,544	0.72	5,408									

* Annual data from USDA/ERS. See Introduction to Annex D for detailed explanation of scenario calculations.

Table D.17. West Africa: Maize, Millet, and Sorghum Total*

	--------Annual data--------			--5-year moving averages--			Scenario I ------(Static Yield)------			Scenario II ----(Declining Yield)----		
Year	Area 000 ha	Calc. yield mt/ha	Prod. 000 mt	Area 000 ha	Yield mt/ha	Prod. 000 mt	Area 000 ha	Yield mt/ha	Prod. 000 mt	Area 000 ha	Yield mt/ha	Prod. 000 mt
1966	19,107	0.58	11,103									
1967	19,969	0.64	12,768									
1968	19,336	0.57	11,004	20,314	0.61	12,381	20,314	0.61	12,381	20,314	0.61	12,381
1969	21,612	0.64	13,851	20,787	0.61	12,661	20,787	0.61	12,674	20,787	0.61	12,629
1970	21,548	0.61	13,179	20,920	0.60	12,614	20,920	0.60	12,612	20,920	0.60	12,535
1971	21,469	0.58	12,504	21,101	0.60	12,633	21,101	0.60	12,629	21,101	0.59	12,519
1972	20,636	0.61	12,533	21,152	0.60	12,593	21,152	0.60	12,593	21,152	0.59	12,456
1973	20,239	0.55	11,099	21,180	0.60	12,632	21,180	0.60	12,655	21,180	0.59	12,492
1974	21,869	0.62	13,648	21,372	0.60	12,828	21,372	0.60	12,854	21,372	0.59	12,658
1975	21,689	0.62	13,374	21,860	0.60	13,085	21,860	0.60	13,102	21,860	0.59	12,859
1976	22,429	0.60	13,486	22,391	0.62	13,839	22,391	0.62	13,825	22,391	0.60	13,539
1977	23,076	0.60	13,818	22,629	0.62	14,050	22,629	0.62	14,027	22,629	0.61	13,707
1978	22,894	0.65	14,867	22,976	0.62	14,321	22,976	0.62	14,265	22,976	0.61	13,906
1979	23,061	0.64	14,705	23,341	0.63	14,693	23,341	0.62	14,578	23,341	0.61	14,180
1980	23,420	0.63	14,730	23,630	0.64	15,042	23,630	0.63	14,889	23,630	0.61	14,458
1981	24,257	0.63	15,345	23,711	0.62	14,612	23,711	0.61	14,519	23,711	0.59	14,050
1982	24,518	0.63	15,562	24,137	0.61	14,674	24,137	0.60	14,551	24,137	0.58	14,034
1983	23,300	0.55	12,721	24,269	0.62	15,049	24,269	0.61	14,843	24,269	0.59	14,300
1984	25,191	0.60	15,012	24,004	0.64	15,365	24,004	0.63	15,073	24,004	0.61	14,527
1985	24,081	0.69	16,606	23,490	0.65	15,165	23,490	0.63	14,803	23,490	0.61	14,254
1986	22,933	0.74	16,922	23,759	0.69	16,310	23,759	0.66	15,785	23,759	0.64	15,220
1987	21,947	0.66	14,564	23,579	0.71	16,858	23,579	0.69	16,241	23,579	0.66	15,670
1988	24,642	0.75	18,447	23,309	0.71	16,483	23,309	0.68	15,888	23,309	0.66	15,292
1989	24,295	0.73	17,749	23,582	0.71	16,761	23,582	0.68	16,094	23,582	0.66	15,462
1990	22,727	0.65	14,731									
1991	24,300	0.75	18,317									

* Annual data from USDA/ERS. See Introduction to Annex D for detailed explanation of scenario calculations.

Table D.18. Central Africa: Maize*

Year	--------Annual data--------			--5-year moving averages--			Scenario I ------(Static Yield)------			Scenario II ----(Declining Yield)----		
	Area 000 ha	Calc. yield mt/ha	Prod. 000 mt	Area 000 ha	Yield mt/ha	Prod. 000 mt	Area 000 ha	Yield mt/ha	Prod. 000 mt	Area 000 ha	Yield mt/ha	Prod. 000 mt
1966	1,120	0.77	866									
1967	1,138	0.75	857									
1968	1,139	0.74	841	1,116	0.81	903	1,116	0.81	903	1,116	0.81	903
1969	1,108	0.84	930	1,112	0.83	924	1,124	0.81	909	1,116	0.80	894
1970	1,076	0.95	1,022	1,107	0.85	946	1,104	0.81	893	1,116	0.79	885
1971	1,101	0.88	969	1,121	0.88	983	1,093	0.81	885	1,116	0.79	876
1972	1,113	0.87	971	1,155	0.88	1,016	1,098	0.81	889	1,116	0.78	868
1973	1,205	0.85	1,023	1,247	0.88	1,099	1,143	0.81	925	1,116	0.77	859
1974	1,282	0.86	1,097	1,335	0.87	1,157	1,181	0.81	956	1,116	0.76	850
1975	1,531	0.94	1,434	1,425	0.85	1,216	1,233	0.81	998	1,116	0.75	842
1976	1,541	0.82	1,261	1,496	0.84	1,250	1,290	0.81	1,044	1,116	0.75	833
1977	1,567	0.81	1,264	1,563	0.82	1,287	1,336	0.81	1,081	1,116	0.74	825
1978	1,555	0.77	1,193	1,575	0.80	1,260	1,344	0.81	1,087	1,116	0.73	817
1979	1,619	0.79	1,285	1,578	0.81	1,281	1,305	0.81	1,056	1,116	0.72	809
1980	1,591	0.82	1,297	1,588	0.83	1,323	1,277	0.81	1,033	1,116	0.72	801
1981	1,555	0.88	1,367	1,606	0.85	1,366	1,266	0.81	1,024	1,116	0.71	793
1982	1,621	0.91	1,473	1,605	0.87	1,395	1,234	0.81	998	1,116	0.70	785
1983	1,643	0.86	1,408	1,658	0.85	1,414	1,259	0.81	1,019	1,116	0.70	777
1984	1,614	0.89	1,432	1,739	0.83	1,446	1,346	0.81	1,089	1,116	0.69	769
1985	1,858	0.75	1,391	1,817	0.80	1,461	1,403	0.81	1,136	1,116	0.68	761
1986	1,957	0.78	1,527	1,897	0.79	1,494	1,444	0.81	1,168	1,116	0.68	754
1987	2,015	0.77	1,550	1,961	0.78	1,523	1,494	0.81	1,209	1,116	0.67	746
1988	2,043	0.77	1,569	1,974	0.80	1,578	1,487	0.81	1,203	1,116	0.66	739
1989	1,934	0.82	1,579	1,978	0.82	1,617	1,477	0.81	1,195	1,116	0.66	731
1990	1,919	0.87	1,667									
1991	1,980	0.87	1,722									

* Annual data from USDA/ERS. See Introduction to Annex D for detailed explanation of scenario calculations.

Table D.19. East Africa: Maize*

	--------Annual data--------			--5-year moving averages--			Scenario I ------(Static Yield)------			Scenario II ----(Declining Yield)----		
Year	Area 000 ha	Calc. yield mt/ha	Prod. 000 mt	Area 000 ha	Yield mt/ha	Prod. 000 mt	Area 000 ha	Yield mt/ha	Prod. 000 mt	Area 000 ha	Yield mt/ha	Prod. 000 mt
1966	3,513	1.00	3,518									
1967	3,423	0.98	3,360									
1968	3,471	1.03	3,575	3,514	1.01	3,541	3,514	1.01	3,541	3,514	1.01	3,541
1969	3,570	0.98	3,503	3,521	1.01	3,551	3,586	1.01	3,614	3,514	1.00	3,506
1970	3,591	1.04	3,751	3,554	1.04	3,684	3,627	1.01	3,656	3,514	0.99	3,471
1971	3,549	1.01	3,567	3,613	1.04	3,746	3,806	1.01	3,836	3,514	0.98	3,435
1972	3,589	1.12	4,026	3,648	1.05	3,816	3,891	1.01	3,922	3,514	0.97	3,400
1973	3,768	1.03	3,883	3,687	1.12	4,129	4,005	1.01	4,036	3,514	0.96	3,364
1974	3,742	1.03	3,851	3,769	1.19	4,499	4,132	1.01	4,165	3,514	0.95	3,329
1975	3,787	1.40	5,319	3,859	1.24	4,794	4,288	1.01	4,322	3,514	0.94	3,294
1976	3,961	1.37	5,417	3,929	1.30	5,113	4,411	1.01	4,446	3,514	0.93	3,258
1977	4,037	1.36	5,501	4,038	1.34	5,404	4,551	1.01	4,587	3,514	0.92	3,223
1978	4,118	1.33	5,479	4,081	1.30	5,309	4,602	1.01	4,638	3,514	0.91	3,187
1979	4,287	1.24	5,305	4,130	1.30	5,375	4,732	1.01	4,769	3,514	0.90	3,152
1980	4,003	1.21	4,845	4,211	1.31	5,507	4,810	1.01	4,848	3,514	0.89	3,116
1981	4,206	1.37	5,746	4,223	1.33	5,597	4,826	1.01	4,864	3,514	0.88	3,081
1982	4,439	1.39	6,160	4,272	1.32	5,623	4,890	1.01	4,928	3,514	0.87	3,046
1983	4,182	1.42	5,927	4,425	1.35	5,982	5,146	1.01	5,187	3,514	0.86	3,010
1984	4,533	1.20	5,438	4,560	1.37	6,250	5,276	1.01	5,318	3,514	0.85	2,975
1985	4,767	1.39	6,637	4,629	1.37	6,344	5,246	1.01	5,288	3,514	0.84	2,939
1986	4,881	1.45	7,087	4,820	1.38	6,674	5,496	1.01	5,539	3,514	0.83	2,904
1987	4,781	1.39	6,631	4,979	1.45	7,213	5,606	1.01	5,650	3,514	0.82	2,869
1988	5,141	1.47	7,576	5,014	1.48	7,441	5,428	1.01	5,471	3,514	0.81	2,846
1989	5,325	1.53	8,135	5,023	1.49	7,477	5,514	1.01	5,558	3,514	0.80	2,811
1990	4,941	1.57	7,775									
1991	4,925	1.48	7,267									

* Annual data from USDA/ERS. See Introduction to Annex D for detailed explanation of scenario calculations.

Table D.20. East Africa: Millet*

Year	--------Annual data--------			--5-year moving averages--			Scenario I ------(Static Yield)------			Scenario II ----(Declining Yield)----		
	Area 000 ha	Calc. yield mt/ha	Prod. 000 mt	Area 000 ha	Yield mt/ha	Prod. 000 mt	Area 000 ha	Yield mt/ha	Prod. 000 mt	Area 000 ha	Yield mt/ha	Prod. 000 mt
1966	1,591	0.72	1,151									
1967	1,690	0.81	1,362									
1968	1,630	0.77	1,259	1,668	0.79	1,318	1,668	0.79	1,318	1,668	0.79	1,318
1969	1,639	0.83	1,362	1,739	0.79	1,379	1,719	0.79	1,363	1,742	0.79	1,381
1970	1,792	0.81	1,454	1,827	0.75	1,378	1,803	0.75	1,360	1,840	0.75	1,388
1971	1,946	0.75	1,458	1,955	0.71	1,392	1,892	0.71	1,347	1,987	0.71	1,415
1972	2,127	0.64	1,358	2,039	0.68	1,389	1,959	0.68	1,334	2,083	0.68	1,419
1973	2,269	0.58	1,327	2,156	0.65	1,407	2,050	0.65	1,338	2,214	0.65	1,445
1974	2,059	0.65	1,346	2,195	0.63	1,386	2,076	0.63	1,311	2,279	0.63	1,439
1975	2,377	0.65	1,548	2,255	0.63	1,418	2,117	0.63	1,331	2,366	0.63	1,488
1976	2,142	0.63	1,350	2,322	0.65	1,504	2,167	0.65	1,404	2,455	0.65	1,591
1977	2,428	0.63	1,519	2,317	0.66	1,525	2,158	0.66	1,421	2,479	0.66	1,632
1978	2,602	0.68	1,759	2,268	0.68	1,539	2,112	0.68	1,433	2,438	0.68	1,654
1979	2,034	0.71	1,450	2,296	0.69	1,586	2,121	0.69	1,465	2,477	0.69	1,711
1980	2,133	0.76	1,615	2,255	0.70	1,585	2,086	0.70	1,466	2,452	0.70	1,723
1981	2,285	0.69	1,588	2,160	0.70	1,515	1,997	0.70	1,401	2,351	0.70	1,649
1982	2,221	0.68	1,512	2,188	0.64	1,402	2,021	0.64	1,295	2,392	0.64	1,533
1983	2,126	0.66	1,408	2,184	0.64	1,393	2,002	0.64	1,277	2,416	0.64	1,541
1984	2,174	0.41	886	2,200	0.60	1,327	2,021	0.60	1,219	2,462	0.60	1,485
1985	2,116	0.74	1,573	2,147	0.58	1,251	1,994	0.58	1,162	2,423	0.58	1,412
1986	2,364	0.53	1,256	2,239	0.58	1,300	2,073	0.58	1,203	2,560	0.58	1,486
1987	1,954	0.58	1,134	2,245	0.63	1,411	2,093	0.63	1,315	2,602	0.63	1,635
1988	2,585	0.64	1,650	2,193	0.60	1,325	2,089	0.60	1,262	2,569	0.60	1,552
1989	2,207	0.65	1,440	2,236	0.61	1,364	2,113	0.61	1,289	2,613	0.61	1,594
1990	1,855	0.62	1,145									
1991	2,580	0.56	1,451									
1991	2,580	0.56	1,451									

* Annual data from USDA/ERS. See Introduction to Annex D for detailed explanation of scenario calculations.

Table D.21. East Africa: Sorghum*

	Annual data			5-year moving averages			Scenario I (Static Yield)			Scenario II (Declining Yield)		
Year	Area 000 ha	Calc. yield mt/ha	Prod. 000 mt	Area 000 ha	Yield mt/ha	Prod. 000 mt	Area 000 ha	Yield mt/ha	Prod. 000 mt	Area 000 ha	Yield mt/ha	Prod. 000 mt
1966	3,428	0.74	2,531									
1967	4,059	0.86	3,502									
1968	3,165	0.77	2,446	3,721	0.79	2,948	3,721	0.79	2,948	3,721	0.79	2,948
1969	3,817	0.81	3,094	3,826	0.81	3,083	3,781	0.81	3,047	3,831	0.81	3,087
1970	4,138	0.76	3,165	3,810	0.79	2,992	3,761	0.79	2,953	3,838	0.79	3,013
1971	3,951	0.81	3,206	4,075	0.79	3,201	3,945	0.79	3,099	4,143	0.79	3,254
1972	3,980	0.77	3,049	4,173	0.78	3,271	4,010	0.78	3,143	4,263	0.78	3,342
1973	4,490	0.78	3,491	4,305	0.80	3,444	4,093	0.80	3,275	4,420	0.80	3,537
1974	4,306	0.80	3,444	4,507	0.78	3,535	4,263	0.78	3,344	4,679	0.78	3,670
1975	4,796	0.84	4,031	4,753	0.79	3,731	4,461	0.79	3,503	4,987	0.79	3,915
1976	4,964	0.74	3,660	4,928	0.80	3,959	4,600	0.80	3,695	5,210	0.80	4,185
1977	5,207	0.77	4,031	5,177	0.80	4,161	4,823	0.80	3,876	5,539	0.80	4,452
1978	5,366	0.86	4,627	5,313	0.81	4,278	4,948	0.81	3,984	5,710	0.81	4,598
1979	5,551	0.80	4,454	5,564	0.84	4,675	5,138	0.84	4,317	6,000	0.84	5,042
1980	5,475	0.84	4,618	5,722	0.83	4,768	5,292	0.83	4,410	6,222	0.83	5,185
1981	6,221	0.91	5,645	5,845	0.80	4,661	5,405	0.80	4,311	6,363	0.80	5,075
1982	5,995	0.75	4,497	5,930	0.73	4,328	5,479	0.73	3,999	6,484	0.73	4,732
1983	5,984	0.68	4,093	6,431	0.71	4,577	5,893	0.71	4,194	7,111	0.71	5,061
1984	5,975	0.47	2,786	6,609	0.70	4,608	6,072	0.70	4,233	7,395	0.70	5,155
1985	7,979	0.73	5,862	6,519	0.68	4,443	6,054	0.68	4,126	7,358	0.68	5,015
1986	7,114	0.82	5,802	6,867	0.73	5,033	6,358	0.73	4,660	7,852	0.73	5,756
1987	5,543	0.66	3,674	6,981	0.77	5,373	6,506	0.77	5,008	8,089	0.77	6,226
1988	7,723	0.91	7,043	6,549	0.74	4,859	6,238	0.74	4,629	7,672	0.74	5,693
1989	6,545	0.69	4,484	6,714	0.70	4,704	6,345	0.70	4,445	7,846	0.70	5,497
1990	5,818	0.57	3,293									
1991	7,940	0.63	5,025									

* Annual data from USDA/ERS. See Introduction to Annex D for detailed explanation of scenario calculations.

Table D.22. East Africa: Maize, Millet, and Sorghum Total*

Year	--------Annual data-------- Area 000 ha	Calc. yield mt/ha	Prod. 000 mt	--5-year moving averages-- Area 000 ha	Yield mt/ha	Prod. 000 mt	Scenario I ------(Static Yield)------ Area 000 ha	Yield mt/ha	Prod. 000 mt	Scenario II ----(Declining Yield)---- Area 000 ha	Yield mt/ha	Prod. 000 mt
1966	8,532	0.84	7,200									
1967	9,172	0.90	8,224									
1968	8,266	0.88	7,280	8,903	0.88	7,807	8,903	0.88	7,807	8,903	0.88	7,807
1969	9,026	0.88	7,959	9,086	0.88	8,013	9,086	0.88	8,024	9,086	0.88	7,973
1970	9,521	0.88	8,370	9,191	0.88	8,055	9,191	0.87	7,969	9,191	0.86	7,872
1971	9,446	0.87	8,231	9,643	0.86	8,339	9,643	0.86	8,282	9,643	0.84	8,104
1972	9,696	0.87	8,433	9,859	0.86	8,475	9,859	0.85	8,399	9,859	0.83	8,160
1973	10,527	0.83	8,701	10,147	0.89	8,981	10,147	0.85	8,649	10,147	0.82	8,346
1974	10,107	0.85	8,641	10,472	0.90	9,420	10,472	0.84	8,819	10,472	0.81	8,437
1975	10,960	0.99	10,898	10,867	0.92	9,944	10,867	0.84	9,156	10,867	0.80	8,697
1976	11,067	0.94	10,427	11,179	0.95	10,576	11,179	0.85	9,546	11,179	0.81	9,034
1977	11,672	0.95	11,051	11,531	0.96	11,090	11,531	0.86	9,883	11,531	0.81	9,306
1978	12,086	0.98	11,865	11,662	0.95	11,126	11,662	0.86	10,055	11,662	0.81	9,439
1979	11,872	0.94	11,209	11,991	0.97	11,636	11,991	0.88	10,551	11,991	0.83	9,904
1980	11,611	0.95	11,078	12,187	0.97	11,860	12,187	0.88	10,724	12,187	0.82	10,025
1981	12,712	1.02	12,979	12,228	0.96	11,773	12,228	0.86	10,575	12,228	0.80	9,805
1982	12,655	0.96	12,169	12,390	0.92	11,353	12,390	0.83	10,222	12,390	0.75	9,311
1983	12,291	0.93	11,428	13,040	0.92	11,951	13,040	0.82	10,657	13,040	0.74	9,612
1984	12,682	0.72	9,110	13,370	0.91	12,185	13,370	0.81	10,770	13,370	0.72	9,615
1985	14,862	0.95	14,071	13,294	0.91	12,039	13,294	0.80	10,577	13,294	0.70	9,367
1986	14,358	0.99	14,146	13,926	0.93	13,007	13,926	0.82	11,402	13,926	0.73	10,146
1987	12,278	0.93	11,439	14,205	0.99	13,997	14,205	0.84	11,973	14,205	0.76	10,729
1988	15,449	1.05	16,269	13,755	0.99	13,625	13,755	0.83	11,362	13,755	0.73	10,091
1989	14,077	1.00	14,059	13,973	0.97	13,545	13,973	0.81	11,292	13,973	0.71	9,902
1990	12,614	0.97	12,213									
1991	15,445	0.89	13,743									

* Annual data from USDA/ERS. See Introduction to Annex D for detailed explanation of scenario calculations.

Table D.23. Southern Africa: Maize*

	--------Annual data--------			--5-year moving averages--			Scenario I ------(Static Yield)------			Scenario II ----(Declining Yield)----		
Year	Area 000 ha	Calc. yield mt/ha	Prod. 000 mt	Area 000 ha	Yield mt/ha	Prod. 000 mt	Area 000 ha	Yield mt/ha	Prod. 000 mt	Area 000 ha	Yield mt/ha	Prod. 000 mt
1966	3,392	1.16	3,943									
1967	3,608	1.28	4,635									
1968	3,817	0.95	3,643	3,834	1.06	4,080	3,834	1.06	4,080	3,834	1.06	4,080
1969	4,062	1.14	4,628	3,959	1.08	4,291	3,958	1.06	4,212	3,834	1.05	4,040
1970	4,293	0.83	3,553	4,047	1.11	4,511	4,016	1.06	4,274	3,834	1.04	3,999
1971	4,016	1.24	4,995	4,094	1.12	4,600	4,052	1.06	4,312	3,834	1.03	3,958
1972	4,048	1.42	5,736	4,174	1.15	4,801	4,105	1.06	4,369	3,834	1.02	3,917
1973	4,050	1.01	4,086	4,171	1.20	5,020	4,083	1.06	4,345	3,834	1.01	3,876
1974	4,461	1.26	5,637	4,195	1.18	4,968	4,077	1.06	4,338	3,834	1.00	3,836
1975	4,281	1.09	4,646	4,232	1.13	4,774	4,087	1.06	4,350	3,834	0.99	3,795
1976	4,133	1.15	4,733	4,262	1.15	4,895	4,097	1.06	4,360	3,834	0.98	3,754
1977	4,233	1.13	4,769	4,114	1.11	4,563	3,948	1.06	4,201	3,834	0.97	3,713
1978	4,202	1.12	4,691	4,135	1.11	4,597	3,961	1.06	4,215	3,834	0.96	3,672
1979	3,720	1.07	3,978	4,286	1.14	4,865	4,068	1.06	4,329	3,834	0.95	3,632
1980	4,387	1.10	4,815	4,314	1.12	4,850	4,070	1.06	4,331	3,834	0.94	3,591
1981	4,887	1.24	6,071	4,347	1.08	4,698	4,075	1.06	4,336	3,834	0.93	3,550
1982	4,372	1.07	4,697	4,460	1.07	4,783	4,148	1.06	4,414	3,834	0.92	3,509
1983	4,367	0.90	3,930	4,472	1.13	5,073	4,145	1.06	4,411	3,834	0.90	3,468
1984	4,289	1.03	4,400	4,367	1.16	5,054	4,042	1.06	4,301	3,834	0.89	3,428
1985	4,444	1.41	6,269	4,352	1.14	4,956	4,031	1.06	4,290	3,834	0.88	3,387
1986	4,365	1.37	5,974	4,378	1.24	5,442	4,086	1.06	4,349	3,834	0.87	3,346
1987	4,294	0.98	4,206	4,484	1.29	5,780	4,182	1.06	4,450	3,834	0.86	3,305
1988	4,501	1.41	6,360	4,547	1.23	5,588	4,221	1.06	4,491	3,834	0.85	3,259
1989	4,817	1.26	6,089	4,604	1.18	5,451	4,255	1.06	4,528	3,834	0.84	3,221
1990	4,759	1.12	5,310									
1991	4,650	1.14	5,290									

* Annual data from USDA/ERS. See Introduction to Annex D for detailed explanation of scenario calculations.Excludes South Africa.

Table D.24. Southern Africa: Millet*

Year	--------Annual data--------			--5-year moving averages--			Scenario I ------(Static Yield)------			Scenario II ----(Declining Yield)----		
	Area 000 ha	Calc. yield mt/ha	Prod. 000 mt	Area 000 ha	Yield mt/ha	Prod. 000 mt	Area 000 ha	Yield mt/ha	Prod. 000 mt	Area 000 ha	Yield mt/ha	Prod. 000 mt
1966	630	0.67	424									
1967	633	0.73	459									
1968	659	0.68	446	651	0.67	438	651	0.67	438	651	0.67	438
1969	672	0.68	457	647	0.67	431	647	0.67	431	703	0.67	468
1970	663	0.61	404	642	0.64	414	656	0.64	423	737	0.64	475
1971	608	0.64	389	632	0.64	407	650	0.64	419	746	0.64	480
1972	609	0.62	375	619	0.63	388	649	0.63	407	766	0.63	480
1973	608	0.67	410	606	0.63	382	644	0.63	406	751	0.63	474
1974	608	0.60	364	610	0.62	379	662	0.62	412	770	0.62	479
1975	595	0.63	373	628	0.61	382	695	0.61	423	812	0.61	495
1976	629	0.59	374	646	0.58	373	726	0.58	419	853	0.58	492
1977	700	0.56	391	656	0.55	359	741	0.55	406	799	0.55	438
1978	700	0.52	362	673	0.52	351	765	0.52	399	832	0.52	434
1979	655	0.45	297	679	0.50	340	795	0.50	399	920	0.50	461
1980	682	0.49	332	654	0.49	319	781	0.49	382	905	0.49	442
1981	657	0.49	320	626	0.48	300	765	0.48	366	888	0.48	426
1982	574	0.50	285	608	0.49	298	765	0.49	376	923	0.49	453
1983	560	0.47	265	584	0.53	312	745	0.53	397	897	0.53	479
1984	565	0.51	290	558	0.54	304	715	0.54	390	816	0.54	444
1985	565	0.71	399	545	0.53	290	696	0.53	370	789	0.53	420
1986	526	0.53	280	548	0.58	319	681	0.58	396	795	0.58	463
1987	511	0.42	216	535	0.59	317	666	0.59	394	817	0.59	484
1988	573	0.72	410	521	0.57	295	661	0.57	374	826	0.57	468
1989	499	0.56	278	516	0.57	294	665	0.57	380	845	0.57	482
1990	498	0.59	293									
1991	500	0.55	276									

* Annual data from USDA/ERS. See Introduction to Annex D for detailed explanation of scenario calculations. Excludes South Africa.

Table D.25. Southern Africa: Sorghum*

Year	Annual data: Area 000 ha	Annual data: Calc. yield mt/ha	Annual data: Prod. 000 mt	5-year moving averages: Area 000 ha	5-year moving averages: Yield mt/ha	5-year moving averages: Prod. 000 mt	Scenario I (Static Yield): Area 000 ha	Scenario I (Static Yield): Yield mt/ha	Scenario I (Static Yield): Prod. 000 mt	Scenario II (Declining Yield): Area 000 ha	Scenario II (Declining Yield): Yield mt/ha	Scenario II (Declining Yield): Prod. 000 mt
1966	653	0.61	396									
1967	798	0.62	492									
1968	701	0.55	388	753	0.58	437	753	0.58	437	753	0.58	437
1969	800	0.62	496	801	0.58	465	802	0.58	465	870	0.58	505
1970	812	0.51	413	798	0.59	473	815	0.59	484	915	0.59	543
1971	896	0.60	535	810	0.61	492	833	0.61	507	955	0.61	581
1972	779	0.69	535	816	0.62	506	855	0.62	530	1,009	0.62	626
1973	761	0.63	483	801	0.64	510	851	0.64	542	993	0.64	632
1974	831	0.68	565	765	0.63	486	831	0.63	527	966	0.63	613
1975	738	0.59	432	725	0.64	462	802	0.64	511	937	0.64	597
1976	718	0.58	413	689	0.65	448	774	0.65	503	910	0.65	591
1977	575	0.72	416	624	0.64	402	705	0.64	454	761	0.64	489
1978	584	0.71	414	604	0.64	384	686	0.64	437	746	0.64	475
1979	507	0.66	334	594	0.64	377	695	0.64	442	804	0.64	511
1980	635	0.54	344	593	0.59	348	709	0.59	416	821	0.59	481
1981	668	0.57	379	595	0.51	305	728	0.51	373	845	0.51	433
1982	572	0.47	267	599	0.48	286	754	0.48	360	910	0.48	434
1983	594	0.34	202	607	0.48	291	773	0.48	371	931	0.48	447
1984	527	0.45	237	596	0.49	290	765	0.49	372	872	0.49	424
1985	672	0.55	369	611	0.48	294	780	0.48	375	884	0.48	425
1986	617	0.61	374	657	0.53	351	816	0.53	436	953	0.53	509
1987	644	0.45	287	694	0.54	373	865	0.54	465	1,061	0.54	570
1988	823	0.59	487	698	0.53	369	884	0.53	467	1,105	0.53	584
1989	715	0.49	349	693	0.51	354	893	0.51	456	1,134	0.51	579
1990	688	0.50	348									
1991	592	0.51	299									

* Annual data from USDA/ERS. See Introduction to Annex D for detailed explanation of scenario calculations. Excludes South Africa.

Table D.26. Southern Africa: Maize, Millet, and Sorghum Total*

	Annual data			5-year moving averages			Scenario I (Static Yield)			Scenario II (Declining Yield)		
Year	Area 000 ha	Calc. yield mt/ha	Prod. 000 mt	Area 000 ha	Yield mt/ha	Prod. 000 mt	Area 000 ha	Yield mt/ha	Prod. 000 mt	Area 000 ha	Yield mt/ha	Prod. 000 mt
1966	4,675	1.02	4,763									
1967	5,039	1.11	5,586									
1968	5,177	0.86	4,477	5,239	0.95	4,955	5,239	0.95	4,955	5,239	0.95	4,955
1969	5,534	1.01	5,581	5,408	0.96	5,187	5,408	0.94	5,109	5,408	0.93	5,013
1970	5,768	0.76	4,370	5,487	0.98	5,399	5,487	0.94	5,181	5,487	0.91	5,018
1971	5,520	1.07	5,919	5,535	0.99	5,499	5,535	0.95	5,237	5,535	0.91	5,019
1972	5,436	1.22	6,646	5,609	1.02	5,696	5,609	0.95	5,306	5,609	0.90	5,023
1973	5,419	0.92	4,979	5,578	1.06	5,912	5,578	0.95	5,293	5,578	0.89	4,982
1974	5,900	1.11	6,566	5,570	1.05	5,832	5,570	0.95	5,277	5,570	0.88	4,927
1975	5,614	0.97	5,451	5,584	1.01	5,618	5,584	0.95	5,284	5,584	0.88	4,887
1976	5,480	1.01	5,520	5,598	1.02	5,716	5,598	0.94	5,282	5,598	0.86	4,838
1977	5,508	1.01	5,576	5,394	0.99	5,325	5,394	0.94	5,061	5,394	0.86	4,640
1978	5,486	1.00	5,467	5,412	0.99	5,333	5,412	0.93	5,051	5,412	0.85	4,581
1979	4,882	0.94	4,609	5,558	1.00	5,583	5,558	0.93	5,170	5,558	0.83	4,604
1980	5,704	0.96	5,491	5,560	0.99	5,517	5,560	0.92	5,128	5,560	0.81	4,514
1981	6,212	1.09	6,770	5,567	0.95	5,303	5,567	0.91	5,076	5,567	0.79	4,409
1982	5,518	0.95	5,249	5,667	0.95	5,367	5,667	0.91	5,150	5,667	0.78	4,397
1983	5,521	0.80	4,397	5,662	1.00	5,676	5,662	0.91	5,179	5,662	0.78	4,394
1984	5,381	0.92	4,927	5,522	1.02	5,647	5,522	0.92	5,062	5,522	0.78	4,295
1985	5,680	1.24	7,037	5,508	1.01	5,539	5,508	0.91	5,035	5,508	0.77	4,232
1986	5,508	1.20	6,627	5,583	1.09	6,111	5,583	0.93	5,181	5,583	0.77	4,318
1987	5,449	0.86	4,709	5,713	1.13	6,469	5,713	0.93	5,309	5,713	0.76	4,359
1988	5,897	1.23	7,257	5,766	1.08	6,252	5,766	0.92	5,333	5,766	0.75	4,311
1989	6,031	1.11	6,715	5,813	1.05	6,099	5,813	0.92	5,363	5,813	0.74	4,282
1990	5,946	1.00	5,950									
1991	5,742	1.02	5,865									

* Annual data from USDA/ERS. See Introduction to Annex D for detailed explanation of scenario calculations. Excludes South Africa.

Table D.27. Sub-Saharan Africa: Maize*

	--------Annual data--------			--5-year moving averages--			Scenario I ------(Static Yield)------			Scenario II ----(Declining Yield)----		
Year	Area 000 ha	Calc. yield mt/ha	Prod. 000 mt	Area 000 ha	Yield mt/ha	Prod. 000 mt	Area 000 ha	Yield mt/ha	Prod. 000 mt	Area 000 ha	Yield mt/ha	Prod. 000 mt
1966	10,922	0.99	10,785									
1967	11,305	1.01	11,383									
1968	10,954	0.95	10,426	11,360	0.98	11,121	11,360	0.98	11,121	11,360	0.98	11,121
1969	11,703	1.02	11,897	11,509	0.99	11,377	11,614	0.98	11,370	11,360	0.97	11,010
1970	11,915	0.93	11,114	11,586	1.01	11,749	11,693	0.98	11,448	11,360	0.96	10,900
1971	11,667	1.03	12,066	11,820	1.02	12,007	11,889	0.98	11,639	11,360	0.95	10,791
1972	11,690	1.13	13,240	12,012	1.03	12,331	11,995	0.98	11,742	11,360	0.94	10,683
1973	12,126	0.97	11,716	12,211	1.06	12,968	12,117	0.98	11,862	11,360	0.93	10,576
1974	12,662	1.07	13,517	12,470	1.07	13,392	12,301	0.98	12,043	11,360	0.92	10,470
1975	12,913	1.11	14,301	12,789	1.07	13,642	12,615	0.98	12,349	11,360	0.91	10,365
1976	12,960	1.09	14,187	13,053	1.09	14,227	12,920	0.98	12,648	11,360	0.90	10,262
1977	13,282	1.09	14,489	13,177	1.09	14,298	13,075	0.98	12,800	11,360	0.89	10,159
1978	13,447	1.09	14,642	13,330	1.07	14,298	13,231	0.98	12,952	11,360	0.89	10,058
1979	13,284	1.04	13,872	13,639	1.08	14,786	13,455	0.98	13,172	11,360	0.88	9,957
1980	13,677	1.05	14,302	13,843	1.09	15,045	13,581	0.98	13,295	11,360	0.87	9,857
1981	14,503	1.15	16,627	13,983	1.07	15,008	13,611	0.98	13,325	11,360	0.86	9,759
1982	14,303	1.10	15,783	14,334	1.07	15,301	13,795	0.98	13,505	11,360	0.85	9,661
1983	14,147	1.02	14,458	14,682	1.10	16,140	14,052	0.98	13,756	11,360	0.84	9,565
1984	15,039	1.02	15,334	14,913	1.11	16,583	14,098	0.98	13,802	11,360	0.83	9,469
1985	15,419	1.20	18,496	15,157	1.10	16,718	13,963	0.98	13,670	11,360	0.83	9,374
1986	15,658	1.20	18,845	15,665	1.14	17,912	14,292	0.98	13,991	11,360	0.82	9,281
1987	15,521	1.06	16,455	16,039	1.18	18,969	14,403	0.98	14,100	11,360	0.81	9,188
1988	16,690	1.22	20,430	16,194	1.18	19,087	14,327	0.98	14,026	11,360	0.80	9,096
1989	16,906	1.22	20,620	16,304	1.17	19,086	14,186	0.98	13,888	11,360	0.79	9,005
1990	16,098	1.17	18,839									
1991	16,355	1.17	19,168									

* Annual data from USDA/ERS. See Introduction to Annex D for detailed explanation of scenario calculations.

Table D.28. Sub-Saharan Africa: Millet*

	--------Annual data--------			--5-year moving averages--			Scenario I ------(Static Yield)------			Scenario II ----(Declining Yield)----		
Year	Area 000 ha	Calc. yield mt/ha	Prod. 000 mt	Area 000 ha	Yield mt/ha	Prod. 000 mt	Area 000 ha	Yield mt/ha	Prod. 000 mt	Area 000 ha	Yield mt/ha	Prod. 000 mt
1966	13,286	0.55	7,303									
1967	14,142	0.62	8,710									
1968	14,015	0.55	7,728	14,268	0.58	8,273	14,268	0.58	8,273	14,268	0.58	8,273
1969	14,982	0.61	9,125	14,679	0.58	8,573	14,621	0.58	8,539	14,760	0.58	8,620
1970	14,917	0.57	8,500	14,766	0.57	8,468	14,707	0.57	8,434	14,889	0.57	8,539
1971	15,338	0.57	8,802	14,834	0.56	8,359	14,796	0.56	8,338	15,082	0.56	8,500
1972	14,576	0.56	8,187	14,846	0.56	8,296	14,855	0.56	8,301	15,197	0.56	8,492
1973	14,353	0.50	7,184	14,856	0.56	8,343	14,906	0.56	8,372	15,311	0.56	8,599
1974	15,045	0.59	8,806	14,909	0.56	8,331	14,999	0.56	8,381	15,497	0.56	8,660
1975	14,966	0.58	8,739	15,277	0.55	8,476	15,369	0.55	8,528	16,033	0.55	8,896
1976	15,605	0.56	8,740	15,663	0.58	9,020	15,733	0.58	9,060	16,558	0.58	9,535
1977	16,417	0.54	8,914	15,788	0.58	9,109	15,842	0.58	9,141	16,745	0.58	9,661
1978	16,280	0.61	9,900	16,024	0.58	9,258	16,076	0.58	9,288	17,063	0.58	9,859
1979	15,674	0.59	9,254	16,116	0.59	9,451	16,212	0.59	9,507	17,309	0.59	10,150
1980	16,143	0.59	9,481	16,055	0.60	9,559	16,191	0.60	9,640	17,341	0.60	10,324
1981	16,067	0.60	9,705	15,828	0.58	9,239	16,017	0.58	9,349	17,168	0.58	10,021
1982	16,112	0.59	9,454	15,901	0.57	8,986	16,176	0.57	9,141	17,416	0.57	9,842
1983	15,142	0.55	8,299	16,108	0.57	9,200	16,428	0.57	9,383	17,795	0.57	10,164
1984	16,041	0.50	7,990	16,112	0.58	9,337	16,527	0.58	9,578	17,921	0.58	10,385
1985	17,177	0.61	10,553	15,789	0.58	9,177	16,397	0.58	9,531	17,725	0.58	10,303
1986	16,087	0.65	10,390	16,150	0.61	9,867	16,853	0.61	10,297	18,355	0.61	11,214
1987	14,496	0.60	8,656	16,208	0.64	10,385	17,049	0.64	10,924	18,614	0.64	11,926
1988	16,947	0.69	11,746	15,966	0.65	10,343	16,924	0.65	10,963	18,446	0.65	11,950
1989	16,335	0.65	10,581	15,696	0.63	9,964	16,784	0.63	10,654	18,237	0.63	11,576
1990	15,007	0.59	8,872									
1991	16,726	0.67	11,172									

* Annual data from USDA/ERS. See Introduction to Annex D for detailed explanation of scenario calculations.

Table D.29. Sub-Saharan Africa: Sorghum*

	--------Annual data--------			--5-year moving averages--			Scenario I ------(Static Yield)------			Scenario II ----(Declining Yield)----		
Year	Area 000 ha	Calc. yield mt/ha	Prod. 000 mt	Area 000 ha	Yield mt/ha	Prod. 000 mt	Area 000 ha	Yield mt/ha	Prod. 000 mt	Area 000 ha	Yield mt/ha	Prod. 000 mt
1966	11,080	0.67	7,380									
1967	11,983	0.73	8,797									
1968	10,979	0.62	6,852	11,889	0.68	8,099	11,889	0.68	8,099	11,889	0.68	8,099
1969	12,507	0.70	8,736	12,170	0.68	8,243	12,122	0.68	8,211	12,238	0.68	8,289
1970	12,895	0.68	8,731	12,268	0.67	8,161	12,219	0.67	8,129	12,370	0.67	8,229
1971	12,486	0.65	8,101	12,612	0.67	8,411	12,581	0.67	8,390	12,824	0.67	8,552
1972	12,470	0.67	8,385	12,756	0.66	8,473	12,764	0.66	8,478	13,057	0.66	8,673
1973	12,703	0.64	8,104	12,951	0.67	8,641	12,995	0.67	8,671	13,348	0.67	8,906
1974	13,225	0.68	9,041	13,247	0.67	8,861	13,327	0.67	8,914	13,769	0.67	9,211
1975	13,873	0.69	9,576	13,595	0.67	9,127	13,677	0.67	9,182	14,268	0.67	9,579
1976	13,965	0.66	9,200	13,954	0.69	9,581	14,016	0.69	9,624	14,751	0.69	10,128
1977	14,209	0.68	9,716	14,215	0.69	9,801	14,263	0.69	9,835	15,076	0.69	10,395
1978	14,496	0.72	10,370	14,342	0.69	9,937	14,389	0.69	9,970	15,273	0.69	10,582
1979	14,531	0.70	10,145	14,683	0.71	10,366	14,770	0.71	10,428	15,769	0.71	11,133
1980	14,510	0.71	10,254	14,954	0.70	10,519	15,080	0.70	10,608	16,152	0.70	11,361
1981	15,668	0.72	11,346	15,143	0.67	10,152	15,324	0.67	10,274	16,425	0.67	11,012
1982	15,566	0.67	10,478	15,325	0.64	9,757	15,589	0.64	9,925	16,784	0.64	10,686
1983	15,437	0.55	8,537	15,617	0.64	10,017	15,927	0.64	10,216	17,252	0.64	11,066
1984	15,442	0.53	8,169	15,536	0.65	10,113	15,936	0.65	10,373	17,280	0.65	11,248
1985	15,971	0.72	11,555	15,170	0.64	9,771	15,755	0.64	10,148	17,030	0.64	10,970
1986	15,263	0.77	11,824	15,386	0.70	10,724	16,056	0.70	11,191	17,487	0.70	12,188
1987	13,734	0.64	8,771	15,320	0.73	11,190	16,115	0.73	11,771	17,594	0.73	12,851
1988	16,521	0.81	13,300	15,157	0.73	11,099	16,066	0.73	11,765	17,511	0.73	12,823
1989	15,110	0.69	10,501	14,851	0.69	10,246	15,881	0.69	10,956	17,255	0.69	11,904
1990	14,039	0.60	8,412									
1991	16,491	0.68	11,132									

* Annual data from USDA/ERS. See Introduction to Annex D for detailed explanation of scenario calculations.

Table D.30. Sub-Saharan Africa: Maize, Millet, and Sorghum Total*

	--------Annual data--------			--5-year moving averages--			Scenario I ------(Static Yield)------			Scenario II ----(Declining Yield)----		
Year	Area 000 ha	Calc. yield mt/ha	Prod. 000 mt	Area 000 ha	Yield mt/ha	Prod. 000 mt	Area 000 ha	Yield mt/ha	Prod. 000 mt	Area 000 ha	Yield mt/ha	Prod. 000 mt
1966	35,288	0.72	25,467									
1967	37,430	0.77	28,891									
1968	35,948	0.70	25,006	37,517	0.73	27,493	37,517	0.73	27,493	37,517	0.73	27,493
1969	39,192	0.76	29,758	38,358	0.74	28,194	38,358	0.73	28,120	38,358	0.73	27,919
1970	39,728	0.71	28,345	38,619	0.73	28,378	38,619	0.73	28,010	38,619	0.72	27,668
1971	39,491	0.73	28,969	39,266	0.73	28,777	39,266	0.72	28,368	39,266	0.71	27,843
1972	38,736	0.77	29,812	39,614	0.73	29,099	39,614	0.72	28,521	39,614	0.70	27,847
1973	39,183	0.69	27,003	40,019	0.75	29,953	40,019	0.72	28,905	40,019	0.70	28,081
1974	40,932	0.77	31,364	40,626	0.75	30,584	40,626	0.72	29,338	40,626	0.70	28,340
1975	41,752	0.78	32,617	41,661	0.75	31,246	41,661	0.72	30,059	41,661	0.69	28,840
1976	42,529	0.76	32,126	42,669	0.77	32,828	42,669	0.73	31,332	42,669	0.70	29,925
1977	43,908	0.75	33,118	43,180	0.77	33,209	43,180	0.74	31,775	43,180	0.70	30,215
1978	44,223	0.79	34,913	43,696	0.77	33,493	43,696	0.74	32,210	43,696	0.70	30,498
1979	43,489	0.77	33,271	44,438	0.78	34,603	44,438	0.75	33,107	44,438	0.70	31,240
1980	44,331	0.77	34,037	44,852	0.78	35,123	44,852	0.75	33,542	44,852	0.70	31,543
1981	46,239	0.81	37,677	44,953	0.77	34,399	44,953	0.73	32,948	44,953	0.68	30,792
1982	45,980	0.78	35,716	45,560	0.75	34,043	45,560	0.71	32,571	45,560	0.66	30,189
1983	44,726	0.70	31,294	46,407	0.76	35,357	46,407	0.72	33,355	46,407	0.66	30,794
1984	46,522	0.68	31,492	46,561	0.77	36,033	46,561	0.72	33,752	46,561	0.67	31,102
1985	48,568	0.84	40,604	46,115	0.77	35,666	46,115	0.72	33,349	46,115	0.66	30,647
1986	47,008	0.87	41,059	47,201	0.82	38,502	47,201	0.75	35,479	47,201	0.69	32,682
1987	43,752	0.77	33,882	47,567	0.85	40,544	47,567	0.77	36,795	47,567	0.71	33,965
1988	50,157	0.91	45,476	47,317	0.86	40,530	47,317	0.78	36,754	47,317	0.72	33,868
1989	48,351	0.86	41,702	46,851	0.84	39,295	46,851	0.76	35,498	46,851	0.69	32,485
1990	45,145	0.80	36,122									
1991	49,572	0.84	41,472									

* Annual data from USDA/ERS. See Introduction to Annex D for detailed explanation of scenario calculations.

Table D.31. Maize Production, with and without Technological Change Scenarios*
(Five-Year Average, 1986–90)

	Actual production (000 mt)	Production: Scenario I (000 mt)	Production: Scenario II (000 mt)	GAP I** (000 mt)	GAP II** (000 mt)	Value GAP I† ($ m)	Value GAP II† ($ m)
Kenya	2,757	2,033	1,241	724	1,516	1-9	227
Malawi	1,337	1,335	1,081	2	256	0	38
Nigeria	1,904	1,028	917	876	987	131	148
Senegal	123	44	33	79	90	11	13
Zaire	750	502	256	248	37	74	
West Africa	4,274	2,824	1,964	1,450	2,310	218	347
Central Africa	1,578	1,203	739	375	839	56	126
East Africa	7,441	5,471	2,846	1,970	4,595	296	689
Southern Africa	5,588	4,491	3,259	1,0997	2,329	165	349
Sub-Saharan Africa	19,087	14,026	9,096	5,061	9,991	759	1,499

Impact on Agricultural Gross Domestic Product

	Av. GDP (1986–89) ($)	Av. AGDP (1986–89) ($ m)	AGDP — value GAP I ($ m)	% increase in AGDP due to GAP I	AGDP — valuel GAP II ($ m)	% increase in AGDP due to GAP II
Kenya	7,894	2,189	2,081	5.19	1,962	11.57
Malawi	4,569	433	433	0.00	395	9.62
Nigeria	34,598	10,639	10,508	1.25	10,491	1.41
Senegal	4,569	995	984	1.12	982	1.32
Zaire	4,663	2,677	2,640	1.40	2,603	2.84

Impact on Daily Calorie Consumption

	Daily calorie consumption per capita			% increase in daily calorie consumption:	
	Actual	GAP I	GAP II	GAP I	GAP II
Kenya	1,029.6	270.4	566.1	36	122
Malawi	1,418.7	2.1	271.7	0	24
Nigeria	145.7	67.0	75.5	85	108
Senegal	148.6	95.5	108.8	180	273
Zaire	189.7	62.7	125.0	49	193

* Annual data from USDA/ERS. See Introduction to Annex D for detailed explanation of scenario calculations.
** The difference between actual production and production under Scenario I (GAP I) and Scenario II (GAP II).
† Value calculated at $150/MT.

Table D.32. Coarse Grain Production, with and without Technological Change Scenarios*

(Five-Year Average, 1986–90)

	Actual production (000 mt)	Production: Scenario I (000 mt)	Production: Scenario II (000 mt)	GAP I** (000 mt)	GAP II** (000 mt)	Value GAP I† ($ m)	Value GAP II† ($ m)
Kenya	2,951	2,332	1,871	619	1,080	93	162
Malawi	1,337	1,335	1,081	2	256	0	38
Nigeria	7,686	7,482	7,283	204	403	31	60
Senegal	813	766	757	47	56	7	8
Zaire***							
West Africa	16,483	15,888	15,292	595	1,191	89	179
Central Africa***							
East Africa	13,625	11,362	10,091	2,263	3,534	339	530
Southern Africa	6,252	5,333	4,311	919	1,941	138	291
Sub-Saharan Africa	40,530	36,754	33,868	3,776	6,662	566	999

Impact on Agricultural Gross Domestic Product

	Av. AGDP (1986–89) ($ m)	AGDP — value GAP I ($ m)	% increase in AGDP due to GAP I	AGDP — valuel GAP II ($ m)	% increase in AGDP due to GAP II
Kenya	2,189	2,096	4.43	2,027	7.99
Malawi	433	433	0.07	395	9.73
Nigeria	10,639	10,608	0.29	10,579	0.57
Senegal	995	988	0.71	987	0.85
Zaire***					

Impact on Daily Calorie Consumption

		Daily calorie consumption per capita		% increase in daily calorie consumption:	
	Actual	GAP I	GAP II	GAP I	GAP II
Kenya	1,102.0	231.2	403.3	27	58
Malawi	1,418.7	2.1	271.7	0	24
Nigeria	588.2	15.6	30.8	3	6
Senegal	982.5	56.8	67.7	6	7
Zaire***					

* Annual data from USDA/ERS. See Introduction to Annex D for detailed explanation of scenario calculations.
** The difference between actual production and production under Scenario I (GAP I) and Scenario II (GAP II).
*** The figures are not included since there is no basis for assuming a close relationship between the production of maize and other coarse grains.
† Value calculated at $150/MT.

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